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ASH CELL GROUNDWATER QUALITY 1976 - 1984 THUNDER BAY TGS EXTENSION

Report No 85-171-K

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ABSTRACT

Data on the physical and chemical characteristics of groundwaters from the coal ash storage area at Thunder Bay TGS from 1976 through 1984, are summarized in this report. A statistical analysis was carried out in order to assess the significance of certain variables and to attempt to establish the nature of any temporal trends in the data. The results of the statistical analysis revealed that there was no significant difference between those years designated as 'pre-operational' and 'post-operational' and that the variability of the data could be explained by natural variations in the site hydrogeochemistry.

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EXECUTIVE SUMMARY

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The purpose of the 'pre-operational' surveys was to obtain baseline data on the hydrology and chemistry of the natural groundwater at the site, before ash storage began. This 'pre-operational' period started in August 1978 and is assumed to have ended at the end of 1981. The second stage, the 'post-operational' period, began with the 1982 survey. These surveys were conducted at the request of Ontario Hydro's Environmental Studies and Assessments Department on behalf of the Thunder Bay Project.

The results of the statistical analysis indicated that:

- the disposal site is not showing any leachate infiltration into the groundwater
- with the available data, there is no statistically significant difference between the pre-operational and post-operational periods
- the variations in analyte concentrations in the groundwater as a function of time reflect the natural variations which can be attributed to variations in site hydrogeochemistry
- no corrective measures are required at this time

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ASH CELL GROUNDWATER QUALITY 1976 - 1984 THUNDER BAY TGS EXTENSION

J. Complak & D. R. Chartier

A survey of groundwater quality in the vicinity of the coal ash disposal site (Cell No 1) at Thunder Bay TGS (TBTGS), was conducted during 1984. This survey was a continuation of the 'pre-operational' groundwater surveys conducted by London Monenco Consultants (LMC) during 1976-78/1,2/ and by Ontario Hydro during 1979-80/3,4,6/, and of the 'post-operational' surveys conducted by Ontario Hydro during 1982-1984/7,8/. The data obtained during the 1984 survey are presented in this report along with an overall analysis and assessment of data from 1978 to 1984.

The purpose of the 'pre-operational' surveys was to obtain baseline data on the hydrology and chemistry of the natural groundwater at the site, before ash storage began. This 'pre-operational' period began in August 1978 and is assumed to have ended at the end of 1981. The second stage, the 'post-operational' period, began with the 1982 survey. The data collected during these two survey periods (reported separately each year /1,2,3,4,6/) can now be analysed to identify any changes in groundwater quality caused by ash placement and ash leachate seepage into the ground, and to assess the need for any type of corrective action.

These surveys were conducted at the request of Ontario Hydro's Environmental Studies and Assessments Department on behalf of the Thunder Bay Project. Monitoring of groundwater quality is required as part of the conditions on the Certificate of Approval issued by the Ontario Ministry of the Environment for the coal ash disposal site for Thunder Bay TGS. Groundwater quality will continue to be monitored during the life cycle of the station.

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ASH CELL HISTORY - TO END OF 1984

The following is a brief outline of the main events in the history of the Ash Disposal Cell No 1, which consists of nine sub-cells, shown in Figure 1.

Pre-operational Phase

1. Construction of Cell No 1 was completed by August, 1978.

2. Placement of slurry of wet (leached) bottom ash and fly ash from Unit No 1, burning US bituminous coal, into sub-cell No 1, began in June, 1979.

3. Placement of dry fly ash from Unit No 1 began in September 1980.

Post-operational Phase

4. Placement of dry fly ash and bottom ash from Units No 2 and 3, burning Western Canadian lignite coal, began in May 1981, during burn trials.

5. Unit No 2 was in commercial service since September 1981. Unit No 3 came into commercial service on July 14, 1982.

6. During 1984 about 12,000 Mg of fly ash was sold through the lignite ash marketing program and therefore not placed in the ash cell.

Table I shows the volumes of ash placed prior to and during 1984.

METHODOLOGY

The following is a general outline of the preparatory field work carried out and the test methods used to obtain the raw data needed to characterize the hydrology and the quality of the groundwaters in the ash disposal area.

1. Piezometer Installation/1/

In May of 1978, 41 piezometers, arranged in 20 nests, and housed in protective surface casings (Figure 2), were installed around Ash Disposal Cell No 1 (Figure 1). In 1979 piezometers 21A and 21B were installed and in 1980 piezometers 22A and 22B. At all piezometer sites, except P78-4, two piezometers were installed. Piezometers identified as A were installed in silty sand layer and B piezometers were installed in the peat-sand layer where near-surface water is present. Piezometer P78-4C was

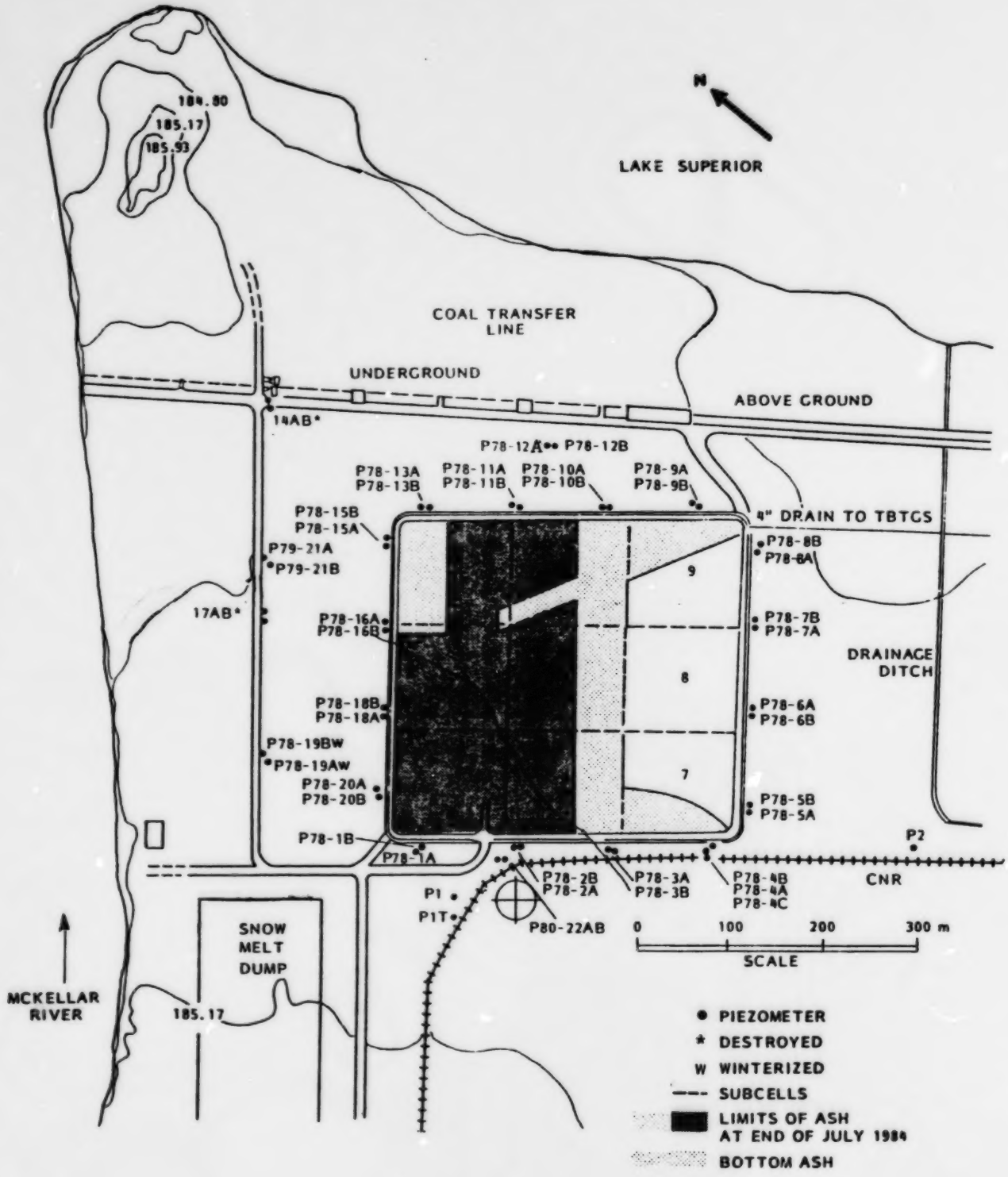


FIGURE 1

ASH DISPOSAL CELL NO. 1
PIEZOMETER NETWORK & LIMIT OF ASH DISPOSAL
THUNDER BAY TGS

TABLE I

ASH DISPOSAL INVENTORY - 1979-84
CELL NO 1 - TBTGS

Date	Bituminous Fly Ash m^3	Lignite Fly Ash m^3	Lignite Bottom Ash m^3	Total Ash Placed m^3
To end of 1979	3,430	-	-	3,430
To end of 1980	21,010	-	-	21,010
To end of 1981	18,755	22,571	3,737	45,063
To end of 1982	16,640	57,485	25,974	100,099
To end of 1983	395	99,871	27,067	127,333
January 1984		12,490	3,720	16,210
February 1984		11,460	4,193	15,653
March 1984		10,080	4,014	14,094
April 1984		5,460	2,509	7,969
May 1984		9,127	3,540	12,667
June 1984		3,952	1,804	5,756
July 1984		2,874	1,003	3,877
August 1984		2,579	439	3,018
September 1984		674	590	1,264
October 1984		6,482	2,316	8,798
November 1984		5,904	2,226	8,130
December 1984		4,579	1,688	6,267
1984 Totals	0	75,661	28,042	103,703
Cumulative Totals	60,230	255,588	84,820	400,638

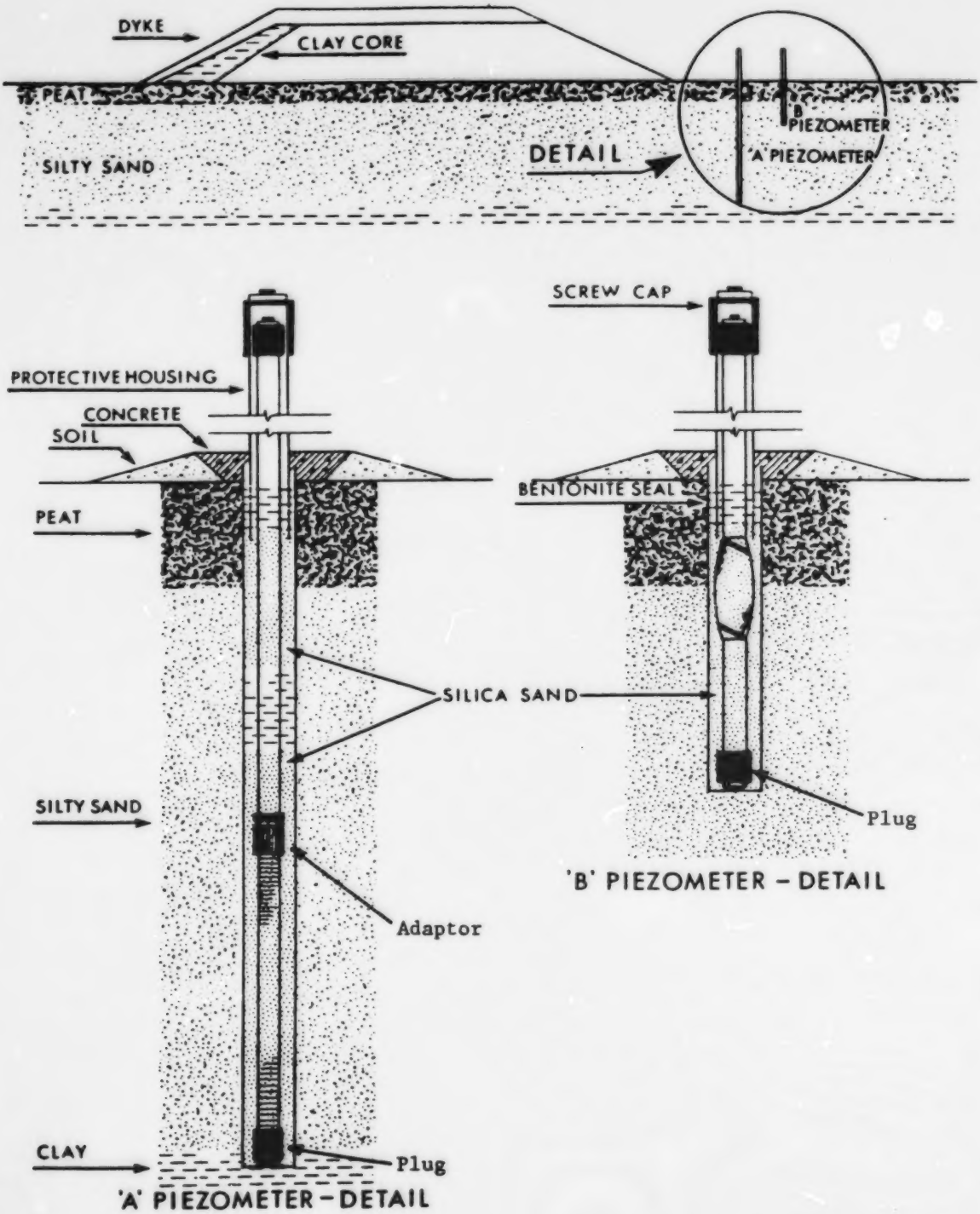


FIGURE 2

THUNDER BAY GENERATING STATION
ASH DISPOSAL CELL No. 1 – GROUNDWATER MONITORING

TYPICAL PIEZOMETER NEST

(after Reference 1)

installed to the base of the silty sand (2.29 m depth) to determine the groundwater gradient across the railway track bed. The depths of all piezometers are shown in Table II and the LMC piezometer construction details/1/ in Table II A.

2. Piezometer and Groundwater Level Surveys

Measurements of the piezometer elevations and of water levels in piezometers were conducted by personnel from the Civil Research Department and TBTGS. The levels are reported as elevations relative to the average lake shoreline level of 182.88 m (600 ft) for the Thunder Bay area.

3. Groundwater Sampling

In general, the following water level measurement and sampling procedures were used by station personnel.

(a) Bailing

- Ground water levels in each piezometer were measured and recorded. The water from each piezometer was bailed out with a hand-operated pump or vacuum pump.

- Four days later the water from each piezometer was bailed out again.

(b) Sampling

- One day after the second bailing in (a) about 1 L of groundwater from each piezometer was collected into an acid cleaned LPE (linear polyethylene) bottle.

- The waters' pH and conductivity were measured immediately with portable pH and conductivity meters.

(c) Preparation

- All samples collected were stored in a refrigerator at about 4°C.

- The samples were filtered as soon as possible using 0.45-μm prewashed Millipore filters.

- A pretreated 500-mL LPE bottle was filled with the filtrate to which were added 2.5 mL of "ULTREX" HNO_3.

- A portion of the remaining filtrate was used for selected field tests.

(d) Shipping

- The remaining filtrate (from c) was kept at about 4°C in a cooler with ice packs, and

TABLE II

ASH CELL NO 1

PIEZOMETER INSTALLATION DETAILS

PIEZOMETER NUMBER	FORMATION MONITORED	PIEZOMETER DEPTH FROM SURFACE	
		m	ft
P78- 1A (1)	SAND	1.44	4.74
P78- 1B	SAND/PEAT	1.13	3.71
P78- 2A	SAND	1.76	5.76
P78- 2B	SAND/PEAT	1.04	3.42
P78- 3A	SAND	1.67	5.49
P78- 3B	SAND/PEAT	0.77	2.52
P78- 4A	SAND	2.16	7.10
P78- 4B	SAND/PEAT	0.89	2.93
P78- 4C	SAND	2.29	7.51
P78- 5A	SAND	2.50	8.19
P78- 5B	SAND/PEAT	1.08	3.53
P78- 6A	SAND	2.11	6.93
P78- 6B	SAND/PEAT	1.06	3.49
P78- 7A	SAND	1.70	5.59
P78- 7B	SAND/PEAT	1.11	3.65
P78- 8A	SAND	1.70	5.57
P78- 8B	SAND/PEAT	1.10	3.61
P78- 9A	SAND	1.80	5.91
P78- 9B	SAND/PEAT	1.16	3.80
P78-10A	SAND	1.43	4.68
P78-10B	SAND/PEAT	1.09	3.59
P78-11A	SAND	1.38	4.54
P78-11B	SAND/PEAT	0.97	3.17
P78-12A	SAND	1.38	4.54
P78-12B	SAND/PEAT	1.05	3.44
P78-13A	SAND	1.52	4.98
P78-13B	SAND/PEAT	1.05	3.43
P78-14A*	SAND	2.57	8.42
P78-14B*	SAND/PEAT	1.40	4.60
P78-15A	SAND	1.83	6.02
P78-15B	SAND/PEAT	1.06	3.49
P78-16A	SAND	1.80	5.92
P78-16B	SAND/PEAT	1.06	3.47
P78-17A*	SAND	1.76	5.79
P78-17B*	SAND/PEAT	1.14	3.73
P78-18A	SAND	1.44	4.72
P78-18B	SAND/PEAT	0.87	2.84
P78-19A	SAND	1.73	5.66
P78-19B	SAND/PEAT	0.98	3.22
P78-20A	SAND	1.51	4.94
P78-20B	SAND/PEAT	1.06	3.47
P79-21A (2)	SAND	1.07	3.5
P79-21B	SAND/PEAT	1.98	6.5
P80-22A (2)	SAND	1.49	4.9
P80-22B	SAND/PEAT	2.41	7.9

* Destroyed

Note:

(1) P78 piezometers were installed by London Monenco Consultants Ltd. (LMC), in 1978. Piezometer depths shown are taken from the LMC Baseline Report - Table A-1.

(2) P79 and 80 piezometers were installed by Ontario Hydro in 1979 and 1980.

PIEZOMETER DATA

PIEZOMETER NUMBER	FORMATION MONITORED	APPROXIMATE SURFACE ELEVATION		MEASURING POINT ELEVATION 24/05/78		HEIGHT OF MEASURING POINT		PIEZOMETER DEPTH FROM SURFACE		SCREENED INTERVAL BELOW SURFACE		MEASURING POINT ELEVATION 28/07/78		(1) PIEZOMETER SCREEN CONSTRUCTION/LENGTH	
		m	ft	m	ft	m	ft	m	ft	m	ft	m	ft		
P78-1A	SAND	184.13	604.10	184.88	606.56	0.75	2.46	1.44	4.74	0.53-1.44	1.74-4.74	184.89	606.59	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-1B	SAND/PEAT	184.13	604.10	185.00	606.94	0.87	2.84	1.13	3.71	0.37-0.67	1.21-2.21	185.00	606.97	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-2A	SAND	184.12	604.08	184.96	606.82	0.84	2.74	1.76	5.76	0.94-1.76	2.76-5.76	184.96	606.83	3 FT (0.91 m)	FIBERGLASS WRAPPED
P78-2B	SAND/PEAT	184.12	604.08	184.96	606.82	0.84	2.76	1.04	3.42	0.28-0.58	0.92-1.92	184.97	606.85	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-3A	SAND	183.85	603.17	184.95	606.80	1.11	3.63	1.67	5.49	0.78-1.67	2.49-5.49	184.96	606.84	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-3B	SAND/PEAT	183.85	603.17	184.93	606.37	0.98	3.20	0.77	2.52	0.01-0.31	0.02-1.02	184.83	606.41	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-4A	SAND	183.98	603.35	184.98	606.63	1.00	3.28	2.16	7.10	1.25-2.16	4.10-7.10	184.92	606.89	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-4B	SAND/PEAT	183.98	603.35	184.87	606.52	0.97	3.17	0.89	2.93	0.13-0.44	0.43-1.43	184.88	606.57	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-4C	SAND	184.00	603.69	184.74	606.10	0.73	2.41	2.29	7.51	1.37-2.29	4.51-7.51	184.75	606.14	3 FT (0.91 m)	FIBERGLASS WRAPPED
P78-5A	SAND	184.09	603.96	184.88	606.28	0.71	2.33	2.50	8.19	1.58-2.50	5.19-8.19	184.81	606.34	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-5B	SAND/PEAT	184.09	603.96	184.75	606.15	0.67	2.19	1.08	3.53	0.31 0.62	1.03-2.03	184.78	606.18	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-6A	SAND	183.87	603.25	184.67	605.87	0.80	2.62	2.11	6.93	1.20 2.11	3.93-6.93	184.69	605.93	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-6B	SAND/PEAT	183.87	603.25	184.68	605.89	0.80	2.62	1.06	3.49	0.30-0.61	0.99-1.99	184.69	605.95	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-7A	SAND	183.77	602.93	184.57	605.55	0.80	2.62	1.70	5.58	0.79 1.70	2.59 5.58	184.59	605.61	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-7B	SAND/PEAT	183.77	602.93	184.64	605.78	0.87	7.85	1.11	3.65	0.35-0.66	1.15-2.15	184.66	605.84	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-8A	SAND	183.88	603.28	184.88	605.90	0.90	2.62	1.70	5.57	0.78-1.70	2.57-5.57	184.89	605.94	3 FT (0.91 m)	FIBERGLASS WRAPPED
P78-8B	SAND/PEAT	183.88	603.28	184.68	605.77	0.76	2.49	1.10	3.61	0.34-0.64	1.11-2.11	184.66	605.83	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-9A	SAND	183.88	603.81	184.48	605.18	0.78	2.57	1.80	5.91	0.89-1.80	2.91-5.91	184.47	605.23	3 FT (0.91 m)	FIBERGLASS WRAPPED
P78-9B	SAND/PEAT	183.88	603.81	184.33	604.78	0.66	2.15	1.16	3.80	0.40-0.70	1.30-2.30	184.33	604.77	1 FT (9.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-10A	SAND	183.71	602.73	184.45	605.16	0.74	2.43	1.43	4.68	0.51-1.43	1.66-4.68	184.47	605.22	3 FT (0.91 m)	FIBERGLASS WRAPPED
P78-10B	SAND/PEAT	183.71	602.73	184.47	605.23	0.76	2.58	1.09	3.59	0.33-0.64	1.09-2.09	184.49	605.28	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-11A	SAND	183.72	602.77	184.54	605.44	0.81	2.67	1.38	4.54	0.40-1.38	1.58-4.54	184.55	605.49	3 FT (0.91 m)	FIBERGLASS WRAPPED
P78-11B	SAND/PEAT	183.72	602.77	184.53	605.42	0.81	2.65	0.97	3.17	0.20-0.51	0.67-1.67	184.55	605.49	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-12A	SAND	183.68	602.62	184.48	605.29	0.81	2.67	1.38	4.54	0.47-1.38	1.54-4.54	184.51	605.34	3 FT (0.91 m)	FIBERGLASS WRAPPED
P78-12B	SAND/PEAT	183.68	602.62	184.57	605.54	0.89	2.92	1.05	3.44	0.28-0.59	0.94-1.94	184.58	605.59	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-13A	SAND	183.84	603.16	184.88	605.94	0.85	2.78	1.52	4.98	0.60-1.52	1.98-4.98	184.70	605.98	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-13B	SAND/PEAT	183.84	603.16	184.48	605.92	0.84	2.76	1.05	3.43	0.28-0.60	0.93-1.93	184.69	605.94	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-14A	SAND	183.86	603.29	184.61	605.69	0.73	2.40	2.57	8.42	1.65-2.57	5.42-8.42	184.82	605.72	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-14B	SAND/PEAT	183.86	603.29	184.66	605.84	0.78	2.55	1.40	4.60	0.49-1.40	1.66-4.60	184.67	605.86	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-15A	SAND	183.93	603.44	184.81	606.33	0.88	2.89	1.83	6.02	0.92 1.83	3.02 6.02	184.82	606.38	3 FT (0.91 m)	FIBERGLASS WRAPPED
P78-15B	SAND/PEAT	183.93	603.44	185.09	607.24	1.16	3.80	1.06	3.49	0.30 0.61	0.99-1.99	185.10	607.27	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-16A	SAND	183.99	603.64	184.81	606.32	0.82	2.68	1.80	5.92	0.89 1.80	2.92-5.92	184.82	606.38	3 FT (0.91 m)	FIBERGLASS WRAPPED
P78-16B	SAND/PEAT	183.99	603.64	184.65	606.51	0.87	2.87	1.06	3.47	0.30 0.60	0.97 1.97	184.87	606.54	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-17A	SAND	184.14	604.13	184.90	606.63	0.76	2.50	1.76	5.79	0.85-1.76	2.79-5.79	DESTROYED		3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-17B	SAND/PEAT	184.14	604.13	184.71	606.21	0.53	2.08	1.14	3.73	0.37-0.68	1.23-2.23	DESTROYED		1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-18A	SAND	184.15	604.18	184.91	606.65	0.76	2.49	1.44	4.72	0.52-1.44	1.72-4.72	184.90	606.64	3 FT (0.91 m)	FIBERGLASS WRAPPED
P78-18B	SAND/PEAT	184.15	604.18	185.06	607.18	0.91	3.00	0.87	2.84	0.12-0.42	0.38-1.38	185.06	607.14	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-19A	SAND	184.19	604.30	185.03	607.05	0.84	2.75	1.73	5.66	0.81-1.73	2.66-5.66	185.03	607.07	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-19B	SAND/PEAT	184.19	604.30	185.03	607.07	0.84	2.77	0.88	3.22	0.22-0.52	0.72-1.72	185.04	607.09	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR
P78-20A	SAND	184.19	604.00	184.88	606.55	0.78	2.55	1.51	4.94	0.59-1.51	1.94-4.94	184.88	606.56	3 FT (0.91 m)	PLASTIC WIRE WOUND
P78-20B	SAND/PEAT	184.19	604.00	184.88	606.55	0.78	2.55	1.06	3.47	0.30-0.60	0.97-1.97	184.89	606.58	1 FT (0.30 m)	FIBERGLASS WRAPPED WITH RESERVOIR

(1) ALL 3 FT (0.91 m) PLASTIC WIRE WOUND SCREENS ARE 10-SLOT (SLOT OPENINGS OF 0.025 cm OR 0.01 IN.)

TABLE IIA

shipped, by air, together with the acidified samples, to Research Division, for analysis.

4. Groundwater Tests and Analyses

(a) Routine Analyses - At TBTGS and Research

All groundwater samples taken were tested at TBTGS for pH conductivity and alkalinity, and occasionally for some other parameters. At Research the samples were tested for Ca, Mg, Na, K, Cl, SO_4, B and Sr concentrations.

(b) Comprehensive Analyses - At Research Division

Due to the greater complexity of the analytical methods required, comprehensive analyses of the samples were carried out by the Analytic Services Section of the Chemical Research Department, Research Division.

The analytes determined are shown below:

Analyte		Analyte	
pH		Beryllium	Be
Conductivity mS/m		Iron	Fe
Alkalinity (OH, CO_3 and HCO_3) as $CaCO_3$		Titanium	Ti
Sulphate	SO_4	Manganese	Mn
Chloride	Cl	Vanadium	V
Nitrate	NO_3	Chromium	Cr
Phosphate	PO_4 *	Copper	Cu
Calcium	Ca	Molybdenum	Mo
Magnesium	Mg	Silver	Ag
Sodium	Na	Cobalt	Co
Potassium	K	Nickel	Ni
Strontium	Sr	Zinc	Zn
Barium	Ba	Arsenic	As
Aluminum	Al	Boron	B
Silicon	Si	Lead	Pb
Thorium	Th	Selenium	Se
Mercury	Hg	Cadmium	Cd

* The 'soluble reactive phosphorus' content of a filtered sample

(c) Analytical Methods

The analytical methods used were primarily those outlined in the Standard Methods for the Examination of Water and Wastewater,

published by the American Public Health Association (14th Edition)/9/. Ion chromatography, neutron activation and other instrumental techniques, currently in general use by the Analytic Services Section, were also used for some determinations.

5. Rationale

(a) Sampling Periods

For 1984, the months of May and August were chosen for groundwater sampling to provide data on groundwater quality during the wet (spring) and dry (summer) periods. The wet conditions in the spring are expected to produce leachate, containing high concentrations of dissolved matter from the ash. These periods represent the extremes of the hydrogeological cycle and provide the most liberal indications of leachate effects on the site.

(b) Field Tests

Because some parameters of natural waters change after sampling, pH and conductivity were determined in the field on fresh samples, and alkalinity, somewhat later (but as soon as possible) in the station's laboratory.

(c) Parameter Significance

Of the many analytes determined, concentrations of Na, Mg, Sr and B are considered to be the main indicators of ash leachate contaminant migration. Alkalinity and SO_4 concentrations are commonly considered to be characteristic of ash leachates but are not considered to be particularly suitable contaminant indicators for this site although they do aid in general characterization of water quality. Alkalinity is subject to change in passage through soil and sulphate concentrations are limited by saturation effects. In addition, SO_4 concentrations in the groundwater in the study area have been found to be highly variable. It is likely that SO_4 concentrations are affected by natural biological activity in the peat layer. Since the shallow, B piezometers are in the sandy/peat layer, they would be expected to be most effected. However, it is also expected that there would be substantial coupling between piezometers in a nest due to the shallow nature of the entire saturated zone and the permeability of the soil between the different levels within a nest.

Sodium is a major component of ash leachate. Its solubility is not limited by saturation effects and it is not expected to undergo significant attenuation in passage through the sandy silt or peat layers. The analysis for sodium is considerably less

time consuming than for SO_4, further supporting the choice of Na as a leachate indicator.

Occasional checks of Sr and B concentrations in piezometer ground water samples are also considered useful. Although generally not appearing in concentrations as high as Na, they are present in leachates at levels greater than ten times those in the local groundwater. Determination of Sr and B is relatively simple.

Magnesium concentrations could also serve as a suitable leachate contaminant indicator, however, care must be taken in data interpretation when pH levels of the groundwater are high. High pH levels tend to promote precipitation of Mg thus lowering its dissolved concentration in the water sample. This could contribute to misinterpretation of the data.

RESULTS OF FIELD AND LABORATORY WORK CONDUCTED IN 1984

1. Piezometer Network Level Survey

In 1984 piezometer elevation survey was carried out by the Civil Research Department on May 15. The 1984 levels, together with those obtained form 1978 through 1984, are summarized in Table III.

2. Groundwater Level Surveys

Measurements of groundwater levels in piezometers on the perimeter of the ash cell were carried out on five occasions during 1984. The results are shown in Table IV. Groundwater levels from 1979 through 1984 are presented in Appendix A.

Lake Superior Water Levels (relative piezometer water monthly means) obtained from Fisheries and Oceans, Services Branch, Ottawa, and monthly total precipitation values, obtained from Environment Canada, Canadian Climate Centre, Downsview, for the Thunder Bay area, are summarized in Table V. Total precipitation values from 1979 through 1984 are listed in Appendix B.

3. Groundwater Characteristics

The analytical results obtained at Thunder Bay TGS and at Research on groundwater samples taken on April 19, and July 27, 1984, are shown in Appendix C. The limited results obtained at Thunder Bay TGS are also included in the summary. Because the TBTGS data were obtained on the same samples that were submitted for the comprehensive analyses, the TBTGS results are shown under a different date (one day after the actual sampling) to avoid computer problems in recalling the two separate sets of data in the future.

TABLE III

ASH CELL GROUNDWATER QUALITY STUDIES - 1978-1984
THUNDER BAY TCS EXTENSION

PIEZOMETER REFERENCE LEVELS
1978-1984

Piezometer Identification		Piezometer Reference Levels, m (Above Reference Level of 182.88 m)													
		Date Surveyed													
		May 24/78	July 28/78	May 8/79	Nov 2/79	June 7/80	Nov 10/80	July 17/81	Nov 2/81	June 9/82	Nov 3/82	May 18/83	May 15/84	Δ	Δ*
P78	1A	2.00	2.01	2.13	2.12	2.17	2.19	2.07	2.15	2.17	2.14	2.19	2.18	-0.01	+0.18
	1B	2.12	2.12	2.24	2.24	2.28	2.30	2.19	2.26	2.29	2.26	2.28	2.28	0.00	+0.16
P78*	2A	2.00	2.00	2.21	2.20	2.24	2.26	2.15	2.21	2.24	2.20	2.22	2.18	-0.04	+0.18
	2B	2.08	2.09	2.21	2.20	2.25	2.27	2.19	2.22	2.25	2.22	2.23	2.28	+0.05	+0.20
P78	3A	2.07	2.08	2.20	2.21	2.25	2.29	2.24	2.25	2.28	2.25	2.27	2.25	-0.02	+0.18
	3B	3.05	1.95	2.06	2.09	2.11	2.15	2.12	2.12	2.14	2.11	2.13	2.11	-0.02	+0.06
P78*	4A	2.02	2.04	2.15	2.15	2.19	2.22	2.10	2.17	2.20	2.16	2.18	2.17	-0.01	+0.15
	4B	1.99	2.00	2.12	2.11	2.16	2.18	2.06	2.14	2.16	2.13	2.14	2.13	-0.01	+0.14
	4C	1.86	1.87	1.99	1.98	2.03	2.05	1.95	2.02	2.04	2.01	2.02	2.04	+0.02	+0.18
P78	5A	1.92	1.93	2.06	2.12	2.19	2.22	2.13	2.22	2.25	2.22	2.28	2.34	+0.06	+0.42
	5B	1.87	1.88	1.99	1.98	2.04	2.08	2.00	2.08	2.12	2.08	2.13	2.15	+0.02	+0.28
P78*	6A	1.79	1.81	1.93	1.91	1.96	1.98	1.95	1.94	1.97	1.93	1.94	1.94	0.00	+0.15
	6B	1.80	1.81	1.93	1.91	1.96	1.98	1.93	1.95	1.96	1.92	1.94	1.94	0.00	+0.14
P78	7A	1.69	1.71	1.82	1.81	1.87	1.90	1.81	1.89	1.92	1.88	1.84	1.85	-0.01	+0.16
	7B	1.76	1.78	1.90	1.89	1.94	1.98	1.90	1.98	2.01	1.98	2.00	2.01	+0.01	+0.25
P78	8A	1.88	1.81	1.93	1.92	2.00	1.99	1.96	1.98	2.02	1.98	1.99	1.99	0.00	+0.19
	8B	1.80	1.78	1.89	1.88	1.96	1.96	1.93	1.94	1.98	1.95	1.96	1.95	-0.01	+0.15
P78*	9A	1.58	1.59	1.73	1.72	1.78	1.80	1.63	1.78	1.81	1.77	1.80	1.82	+0.02	+0.24
	9B	1.45	1.45	1.59	1.60	1.64	1.69	1.52	1.66	1.71	1.67	1.69	1.74	+0.05	+0.29
P78	10A	1.57	1.59	1.71	1.70	1.74	1.76	1.63	1.74	1.80	1.77	1.78	1.79	+0.01	+0.22
	10B	1.59	1.61	1.73	1.73	1.76	1.80	1.66	1.78	1.83	1.79	1.77	1.80	+0.03	+0.21
P78*	11A	1.66	1.67	1.80	1.78	1.80	1.84	1.76	1.79	1.82	1.78	1.79	1.80	+0.01	+0.14
	11B	1.65	1.67	1.79	1.79	1.80	1.84	1.77	1.80	1.83	1.79	1.80	1.81	+0.01	+0.16
P78*	12A	1.61	1.63	1.76	1.76	1.79	1.76	1.81	1.75	1.76	1.75	1.73	1.77	+0.04	+0.16
	12B	1.60	1.70	1.81	1.82	1.87	1.84	1.88	1.84	1.86	1.85	1.86	1.90	+0.04	+0.21
P78	13A	1.81	1.82	1.96	1.94	2.00	2.01	1.91	2.00	2.02	1.99	2.01	2.03	+0.02	+0.22
	13B	1.81	1.81	1.94	1.93	1.99	2.01	1.91	2.00	2.05	2.00	2.00	2.01	+0.01	+0.48
P78	14A	1.73	1.74	-	-	-	-	-	-	-	-	-	-	-	-
	14B	1.78	1.79	-	-	-	-	-	-	-	-	-	-	-	-
P78	15A	1.93	1.96	2.06	2.05	2.08	2.10	1.94	2.06	2.09	2.06	2.08	2.08	0.00	+0.15
	15B	2.21	2.22	2.33	2.34	2.36	2.38	2.23	2.34	2.36	2.34	2.35	2.35	0.00	+0.14
P78	16A	1.93	1.96	2.06	2.05	2.08	2.11	2.05	2.08	2.12	2.08	2.11	2.11	0.00	+0.18
	16B	1.98	1.99	2.10	2.13	2.17	2.20	2.13	2.17	2.23	2.18	2.22	2.27	+0.05	+0.29
P78*	18A	2.03	2.02	2.14	2.13	2.15	2.18	2.05	2.16	2.20	2.16	2.17	2.18	+0.01	+0.15
	18B	2.18	2.18	2.30	2.31	2.32	2.35	2.23	2.33	2.37	2.33	2.35	2.36	+0.01	+0.18
P78*	19A	2.15	2.15	2.30	2.30	2.32	2.36	2.13	2.30	2.32	2.29	2.34	2.34	0.00	+0.19
	19B	2.15	2.16	2.30	2.29	2.31	2.34	2.11	2.28	2.30	2.28	2.30	2.30	0.00	+0.15
P78	20A	2.00	2.00	2.13	2.13	2.16	2.18	2.04	2.16	2.19	2.16	2.19	2.18	-0.01	+0.18
	20B	2.00	2.01	2.11	2.10	2.16	2.18	2.03	2.18	2.24	2.21	2.23	2.28	+0.05	+0.28
P79	21A	-	-	-	1.87	1.90	1.95	1.83	1.99	2.00	1.99	2.02	2.04	+0.02	+0.17
	21B	-	-	-	1.98	2.01	2.06	1.76	1.90	1.91	1.90	1.96	1.97	+0.01	-0.91
P80*	22A	-	-	-	-	2.15	2.17	2.12	1.98	2.01	-	1.99	-	-	-0.16
	22B	-	-	-	-	2.01	2.02	1.96	2.14	2.17	-	2.16	-	-	+0.13

* Clustered wells.
\- Two wells - installed and elevations measured on June 11, 1980.
Δ Difference from previous level survey, in metres.
Δ* Difference from original 1978, 1979, or 1980 levels, in metres.

TABLE IV

ASH CELL GROUNDWATER QUALITY - 1984
THUNDER BAY TGS EXTENSION

RELATIVE PIEZOMETER AND LAKE WATER LEVELS - 1984
(Relative to Average Shoreline Level of 182.88 m)

Piezometer Identification	Relative Water Levels in Piezometers (m)				
	Dates Measurements Taken				
	April 19, 1984	July 6, 1984	July 26, 1984	Sept 18, 1984	Oct 26, 1984
P78 1A	1.18	1.13	1.04	1.10	1.32
P78 1B	1.28 (F)	1.26	1.16	1.15	1.33
P78 2A	1.24	1.29	1.24	1.24	1.28
P78 2B	1.39	1.40	1.34	1.31	1.37
P78 3A	1.48	1.32	1.26	1.21	1.27
P78 3B	1.50	1.32	1.27	1.20	1.28
P78 4A	1.25	1.33	1.28	1.19	1.26
P78 4B	1.33	1.27	1.19	1.18	1.24
P78 4C	1.53	1.27	1.23	1.20	1.25
P78 5A	1.31 (F)	1.32	1.22	1.09	1.14
P78 5B	1.12 (F)	1.17	1.13	1.12	1.14
P78 6A	1.28	1.14	1.13	1.04	1.08
P78 6B	1.26	1.05	1.13	1.06	1.08
P78 7A	0.90	1.08	1.01	1.06	1.08
P78 7B	1.10	1.15	1.10	1.06	1.06
P78 8A	1.09	1.12	1.05	1.04	1.07
P78 8B	1.07	1.14	1.06	1.03	1.07
P78 9A	0.87	0.90	0.91	0.89	0.90
P78 9B	1.04	0.90	0.83	0.87	0.87
P78 10A	1.19	1.08	1.08	1.03	1.04
P78 10B	0.63	1.06	1.04	1.05	1.04
P78 11A	1.08	1.09	1.06	1.04	1.04
P78 11B	1.05	1.08	1.05	1.04	1.04
P78 12A	1.02 (F)	1.05	-	-	0.99
P78 12B	1.09	1.11	-	-	1.03
P78 13A	1.05	1.08	1.04	1.04	1.04
P78 13B	1.04	1.07	1.02	1.03	1.04
P78 14A	-	-	-	-	-
P78 14B	-	-	-	-	-
P78 15A	1.07	1.08	1.06	1.04	1.08
P78 15B	1.07	1.08	1.08	1.04	1.07
P78 16A	1.13	1.13	1.09	1.10	1.16
P78 16B	1.12	1.18	1.15	1.06	1.15
P78 17A	-	-	-	-	-
P78 17B	-	-	-	-	-
P78 18A	1.27	1.24	1.16	1.01	1.19
P78 18B	1.30	1.26	1.17	1.02	1.20
P78 19A	1.32	1.25	1.17	0.75	1.09
P78 19B	1.30	1.25	1.18	0.84	1.12
P78 20A	1.47	1.34	1.29	1.19	1.26
P78 20B	0.98 (F)	1.36	1.29	1.19	1.27
P79 21A	1.22	0.27	1.11	0.66	0.96
P79 21B	1.23	0.12	1.12	0.67	1.00
P80 22A	1.57	1.41	1.38	1.29	1.32
P80 22B	1.63	1.42	1.40	1.21	1.33
Lake Water (1)	0.13	0.39	0.39	0.37	0.35

(1) Relative Average Monthly Lake Levels (relative to 182.88 m average lake level) for Station 10050, Thunder Bay Harbour. Obtained from Marine Environmental Data, Services Branch, Fisheries and Oceans, Ottawa.

TABLE V

LAKE SUPERIOR WATER LEVELS AND TOTAL PRECIPITATION
1979 - 1984

Year	Month	Lake Superior Water Level m (1) (monthly means)	Total Precipitation mm (2)	Year	Month	Lake Superior Water Level m (1) (monthly means)	Total Precipitation mm (2)
1979	January	-0.02	16.2	1982	January	-0.07	58.1
	February	-0.05	61.3		February	-0.11	11.4
	March	-0.01	102.9		March	-0.14	64.8
	April	0.05	55.4		April	-0.07	42.0
	May	0.25	96.5		May	0.09	77.1
	June	0.40	52.4		June	0.15	73.3
	July	0.43	37.8		July	0.24	200.3
	August	0.42	68.1		August	0.30	126.3
	September	0.40	47.5		September	0.31	50.1
	October	0.35	91.1		October	0.38	141.6
	November	0.34	15.9		November	0.40	52.4
	December	0.26	23.9		December	0.34	43.2
1980	January	0.19	57.2	1983	January	0.29	37.1
	February	0.13	11.9		February	0.23	34.2
	March	0.05	36.9		March	0.20	42.1
	April	0.06	20.5		April	0.21	59.4
	May	0.12	32.8		May	0.25	47.9
	June	0.17	58.7		June	0.34	67.9
	July	0.21	127.7		July	0.38	62.4
	August	0.24	124.0		August	0.36	108.0
	September	0.29	174.9		September	0.34	83.8
	October	0.26	63.5		October	0.38	74.7
	November	0.20	40.7		November	0.35	103.7
	December	0.09	47.5		December	0.29	37.7
1981	January	0.00	7.8	1984	January	0.22	2.1
	February	-0.04	55.5		February	0.17	32.4
	March	-0.05	33.1		March	0.12	15.7
	April	0.05	49.4		April	0.13	26.5
	May	0.13	59.5		May	0.23	51.7
	June	0.22	170.2		June	0.33	120.7
	July	0.25	7.4		July	0.39	97.0
	August	0.23	85.6		August	0.40	86.5
	September	0.16	38.1		September	0.37	46.5
	October	0.14	71.4		October	0.35	82.6
	November	0.08	23.6		November	0.31	32.1
	December	0.01	30.2		December	0.27	71.0

(1) Calculated difference between monthly means and the average shoreline level of 182.88 m. From Marine Environmental Data for Thunder Bay (Harbour), Station 10050, obtained from the Services Branch, Fisheries and Oceans, Ottawa.

(2) Total monthly precipitation of rain and snow, calculated from 'Total Daily Precipitation of Rain and Snow' data, for Thunder Bay A (airport), provided by Environment Canada, Atmospheric Environment Service, Canadian Climate Centre, Downsview, Ontario.

DISCUSSION OF 1984 FIELD AND LABORATORY RESULTS

1. Piezometer Reference Levels

The piezometer reference levels for 1984, given in Table III, show that from May 18, 1983, to May 15, 1984, only relatively small changes occurred in most piezometer levels. Most of the changes were small increases in elevations. The biggest increase was 6 cm in piezometer 5A. Increases of 5 cm occurred in piezometers 2B, 9B and 16B. The level of piezometer 2A decreased by 4 cm. The remaining changes were of smaller magnitude, eight of which were slight (2 cm) decreases and seventeen slight (4 cm) increases. These level changes indicate that little movement occurred in ground levels over the year.

Comparison of the 1984 elevations with the original (1978-80) levels shows that in all but two cases the piezometer levels rose. The smallest increase (6 cm) occurred with piezometer 3B. The greatest apparent decrease in elevation occurred with piezometer 22A which decreased by 16 cm.

2. Groundwater Levels

The piezometer water level data acquired in 1984 (Table IV) show that groundwater levels in the ash cell area varied from lows of 0.12 m and 0.27 m above the average shoreline water level of 182.88 m (reference level), in piezometer 21A and 21B on July 6, 1984, to highs of 1.57 and 1.63 m above the average shoreline level, in piezometer 22A and 22B on April 19, 1984. Other high levels occurred in piezometers 2A, 2B, 3A, 3B, 4A, 4B, 4C, 15A to 22A. It appears, therefore, that high groundwater levels exist at the north-west corner and west side of the ash cell where most ash has been stored.

The relationships between groundwater levels in several selected piezometers, lake water levels and total weekly precipitation, presented in Figure 3, show that groundwater levels were highest at the start of the survey in April and gradually decreased to their lowest in September and then rose again in October. This pattern of groundwater level changes was also evident in the data acquired in previous years.

Superimposed upon this simple pattern are the relative changes in the groundwater mound under the site. These changes are illustrated for 3 dates in 1984 in Figure 4. When compared to other years it is apparent that details of the groundwater 'isopleth' vary considerably and that the groundwater flow patterns are subject to both seasonal and yearly changes.

As in 1983, during the period when groundwater levels were highest in April, the lake water was at its low level. The

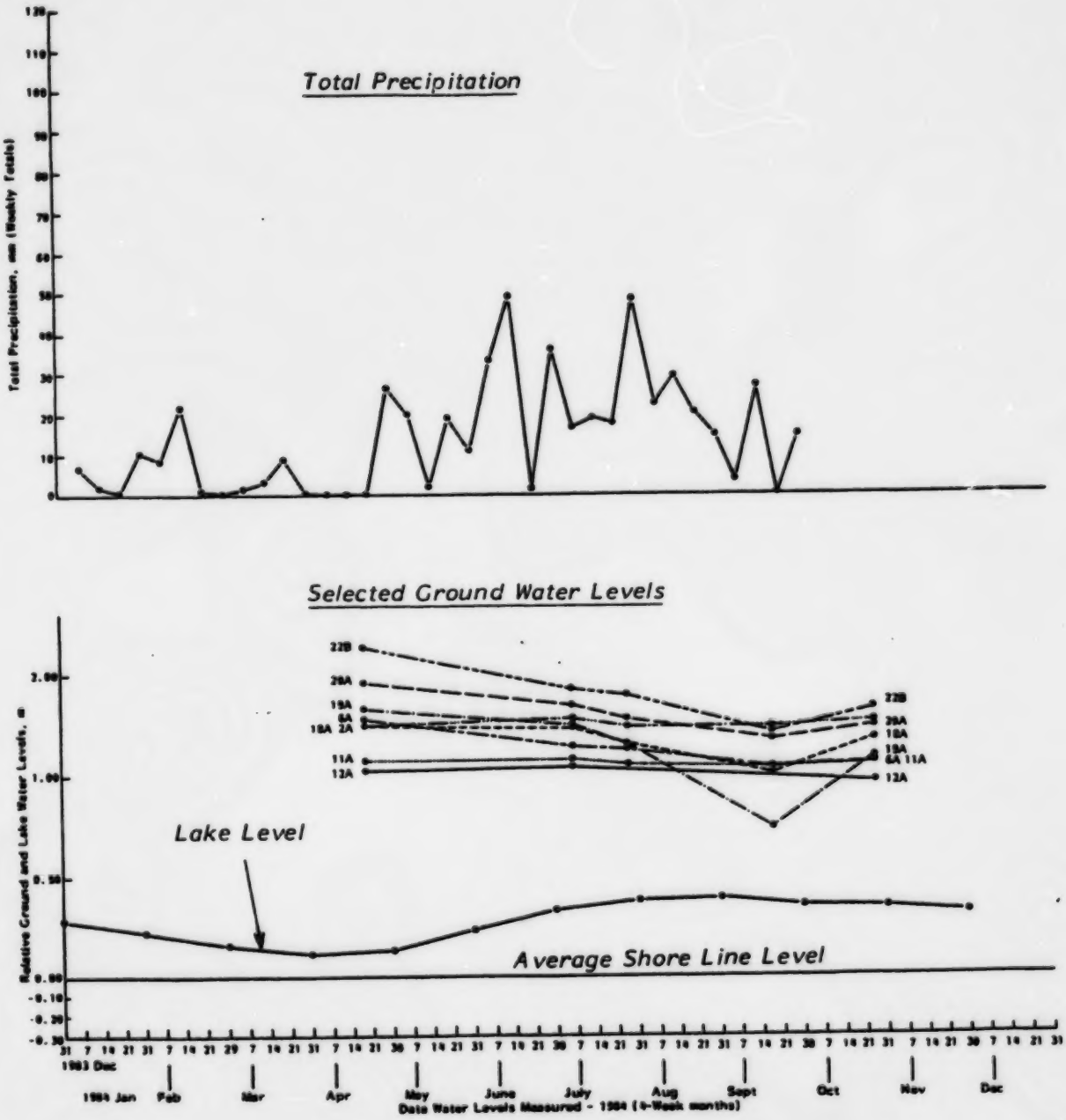


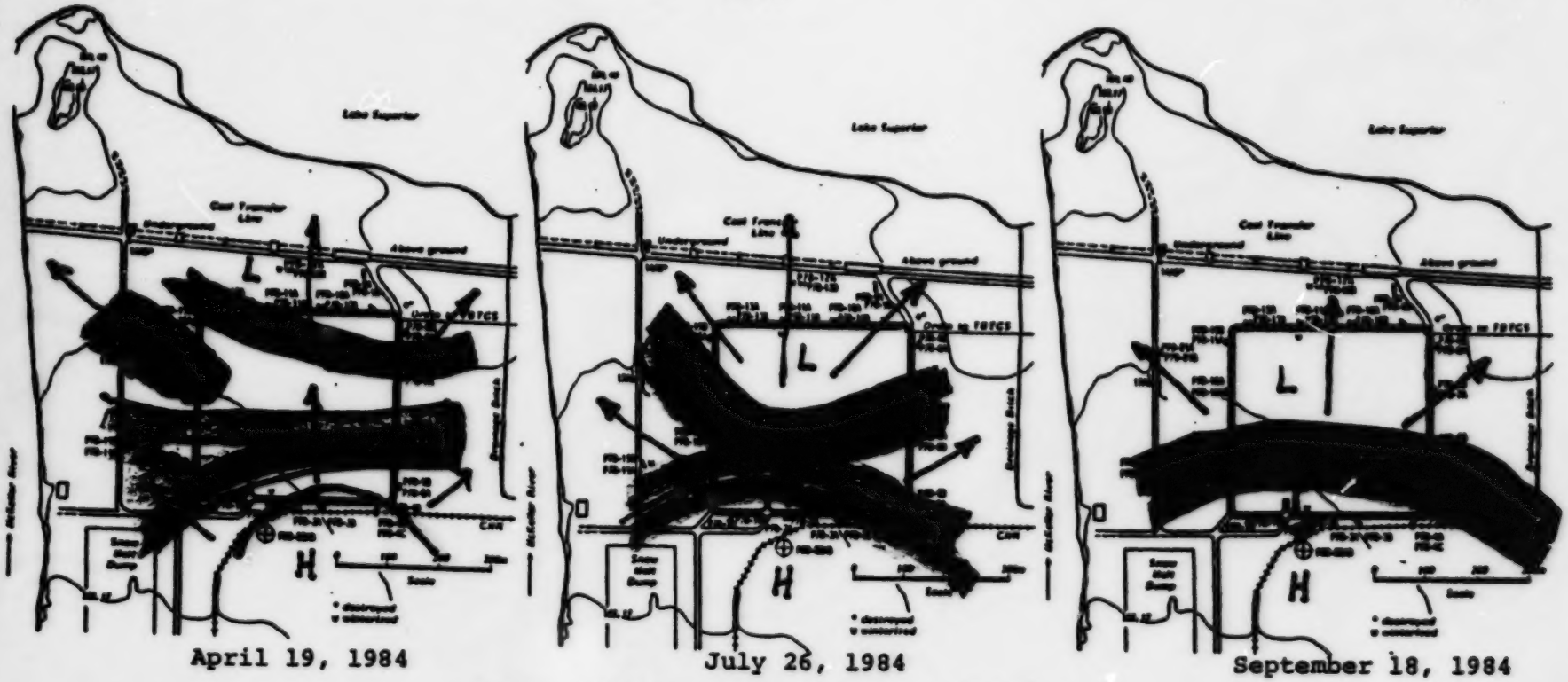
FIGURE 3

ASH CELL GROUND AND LAKE WATER LEVELS (m)*
AND TOTAL PRECIPITATION (mm)

***(Relative to Average Lake Shoreline Level of 182.88m)**

FIGURE 4

ASH CELL STORAGE AREA
GROUNDWATER FLOWS
1984



Relative Piezometer Levels Above 182.88 m

0.87 - 1.10 m

1.11 - 1.25 m

1.26 - 1.40 m

1.41 - 1.63 m

Direction of groundwater flow

85-171

gradual increase in the lake water levels from April to its peak in the summer months was accompanied by a decrease in groundwater levels. The plot of total precipitation data shows low precipitation conditions from mid-February through April indicating no significant effects on groundwater levels.

3. Groundwater Quality

The complete list of groundwater analyses for 1984 appears in Appendix C. The specific discussion of 1984 groundwater quality has been included within the discussion of historical trends and outliers in the next section. This is justified by the consistency of groundwater chemistry which is addressed in the Statistical Analysis section.

HISTORICAL SUMMARY AND ANALYSIS

INVESTIGATION OF OUTLIERS

As data were accumulated and reported every year certain observations were made and an attempt was made to explain outliers in terms of leachate formation/migration or natural site variations. Since sufficient data had not been collected until this point to allow a statistical analysis, these methods of visual inspection were relied upon heavily. There were two methods used to aid in the evaluation of the accumulated data. Piper trilinear diagrams have been used for some time to summarize major ion chemistry and recently, selected piezometers have been specifically evaluated for trends or major changes in significant analytes.

1. Piper Diagrams

Since 1980 /3/ Piper trilineer diagrams have been routinely used to aid in the identification of outliers. In effect, Piper diagrams are 8 parameter visual correlation diagrams which serve to emphasize trends in major ion chemistry. Any consistent migration of points from the major groupings is indicative of water quality changes which require further, detailed explanation.

A compilation of outliers, determined from Piper diagrams, for the years 1979 to 1984 is provided in Table VI. The major ion which is responsible for the excursion from the main group of points has been identified along with the measured concentration of the analyte. Also, the date, piezometer number, Sr and B values as well as a flag for cation/anion ratios that differ by >10% have been included. This was done in order to establish whether there was a true indication of leachate formation.

TABLE VI Summary of Outliers from Piper Diagrams

YEAR	DATE	PIEZOMETER	OUTLIER ANALYTE (X mg/L)	Sr (mg/L)	B (mg/L)	cation -anion >10%
1984	April 19	16A	SO_4 (233)	0.21	1.8	*
		16B	Na (40)	0.24	0.73	
		21B	SO_4 (27)	0.06	0.11	
	July 26	5B	" (130)	0.11	0.08	
		16A	" (120)	0.19	2.4	
		16B	" (130)	0.19	0.61	
		20A	" (230)	0.20	1.0	
		20B	" (230)	0.24	0.50	
1983	May 6	16A	" (290)	<5	0.95	*
		16B	" (310)	<5	0.16	
		19A	Na (35)	<5	0.15	*
		19B	Na (14)	<5	0.02	
	August 11	1B	SO_4 (140)	0.14	0.56	
		3B	" (390)	0.24	0.28	
		16A	" (240)	0.16	0.74	*
		16B	" (320)	0.12	0.50	*
1982	May 19	1B	" (168)	<1	1.50	
		3B	" (153)	<1	0.90	
		5B	" (148)	1.60	1.50	
		6B	" (304)	<1	<0.50	
		9A	" (282)	<1	1.10	
		19B	Cl (32)	<1	1.00	
		21B	Cl (58)	<1	1.30	
	July 23	19A	Cl (53)	0.14	<0.50	
		19B	Na (21)	0.08	<0.50	
	October 15	16A	SO_4 (188)	0.15	1.80	
		16B	" (118)	0.09	1.6	
	November 18	16A	" (212)	0.16	<0.50	
		16B	" (241)	0.10	<0.50	
		21B	Cl (38)	0.05	<0.50	
1981	March 10	18A	SO_4 (70)	0.07	-	*
		19B	" (120)	0.03	-	*
	May 12	4B	Na (94)	0.10	0.40	
		19A	Cl (172)	0.16	<0.10	
	June 3	19A	" (27)	<0.02	<0.05	*
	October 28	7B	SO_4 (340)	0.31	0.002	*
		8A	" (476)	0.31	0.50	*
		9B	" (225)	0.06	0.55	*
		20A	Na (100)	0.06	0.30	*
		21A	SO_4 (120)	-	-	*

TABLE VI Summary of Outliers from Piper Diagrams (continued)

YEAR	DATE	PIEZOMETER	OUTLIER ANALYTE (X mg/L)	Sr (mg/L)	B (mg/L)	cation -anion >10%
1980	May 6	4B	SO_4 (160)	0.50	-	*
		4C	" (150)	0.59	-	*
		5A	" (118)	0.41	-	*
		6B	" (450)	0.30	-	*
		7A	" (186)	0.52	-	*
		9A	" (138)	0.14	-	*
		9B	" (131)	0.23	-	*
		11B	" (132)	0.43	-	*
		13A	" (258)	0.29	-	*
		16B	" (134)	0.42	-	*
		18A	" (108)	0.43	-	
		19A	" (155)	0.42	-	*
		19B	" (123)	0.37	-	
		20A	" (180)	0.11	-	
		.....	Na (100)			
		20B	SO_4 (145)	0.55	-	
	May 13	2A	" (134)	0.041	0.12	
		6B	" (350)	0.14	0.02	
		19A	Cl (53)	0.088	0.06	
		20A	Na (100)	0.055	0.12	
		.....	SO_4 (160)			
		20B	" (146)	0.072	<0.01	
		21A	Cl (66)	0.07	0.03	
	June 27	1A	SO_4 (379)	<0.03	<0.05	*
		1B	" (248)	<0.03	0.25	*
		8A	Na (83)	0.031	<0.05	*
		10A	SO_4 (139)	<0.03	0.05	
		11B	Cl (104)	0.16	0.25	*
		15A	" (78)	<0.03	<0.05	
		16B	" (140)	<0.03	<0.05	*
		19A	" (70)	0.063	<0.05	
	August 11	3A	" (40)	<0.03	-	*
		11B	" (62)	<0.03	-	*
	October 28	18B	SO_4 (115)	0.23	0.80	
		21B	Cl (86)	<0.10	0.80	*
1979	May 3	1B	SO_4 (406)	<5.0	<1.0	
		2B	" (125)	<5.0	<1.0	*
	September 11	6B	" (640)	-	0.28	*
		8B	" (256)	-	0.28	

It is apparent that there are some piezometers which consistently appear as outliers over a period of years (16, 19 and 20). Also, there are cases where analysis error or biological factors seem to have played an inordinate roll (this is particularly true for May 6, 1980). It is important to explain the reasons for these excursions.

The most general observation to be made is the frequency of appearance of sulphate as a cause for outlying values. In most of those instances there is a problem with the cation/anion ratio which may indicate an ionic imbalance expected from inordinate biological production of sulphate. When several piezometers show a sulphate excursion on a particular date (May 6, 1980) it is also possible that analytical error might explain the results. However, in all of the sulphate outliers there was never an increase in any of the leachate indicator ions.

The Piper diagrams for the April 19 and July 26, 1984 groundwater surveys have been included in this section (see Figures 5 and 6) as they are typical of the majority of diagrams of major ion chemistry produced for previous yearly summaries. The magnitude of the parameter excursions from the main group of points is similar to those observed throughout the site history and there is no indication of leachate formation.

2. Plots of Analytes for Selected Piezometers

In the 1983 site report /8/ 6 piezometers were chosen to provide an early indication of groundwater contamination by ash leachate. These piezometers (1B, 3B, 12B, 15B, 18A and 20A) were chosen after an historical assessment of data indicated that they were the most variable of all of the boreholes being monitored.

The data for these piezometers has been augmented with the 1984 data. The plots of pH, HCO_3 alkalinity, sulphate, and 'indicator ions' (Na, Mg, Sr and B) versus time are shown as Figures 7-13.

The plot of pH vs Time (Figure 7) indicates that no location showed consistently high pH values which would be considered indicative of leachate formation. Also, there was only a small amount of scatter in the data.

The plot of HCO_3 alkalinity vs Time (Figure 8) shows considerably more variability than the pH plot. Over time, boreholes 20A and 3B often had elevated bicarbonate alkalinity. However, these elevated values were not always consistent and on one occasion (August 1983) 3B had the lowest alkalinity value while having the highest sulphate. In 1979 there were anomalous (high) alkalinity values for 1B, 3B and 20A which may be explained by excessive biological activity. Unfortunately, no definitive and consistent explanation of these excursions is apparent.

FIGURE 5

MAJOR ION CHEMISTRY
TBTGS ASH
APR 19 1984
TYPE - WATER
ASH CELL AREA GROUNDWATER QUALITY - TBTGS - 1984

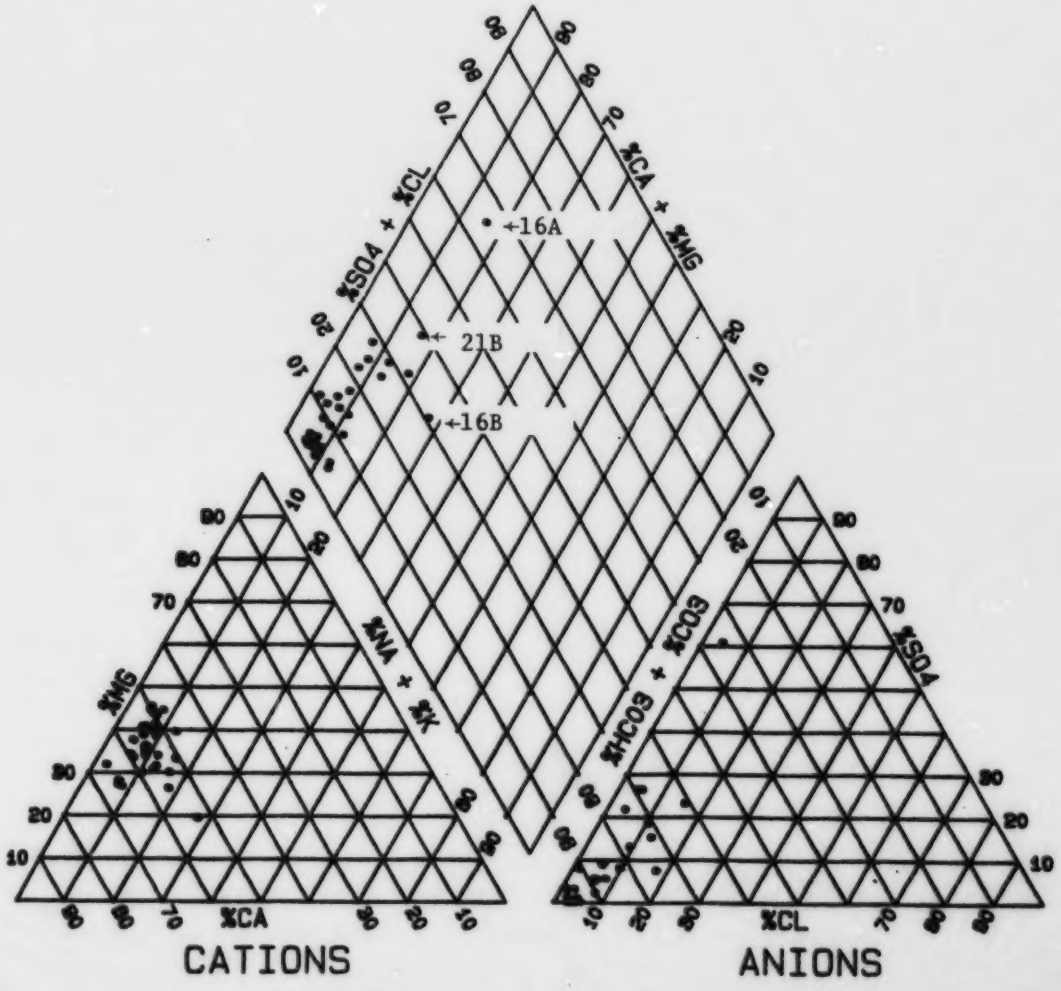
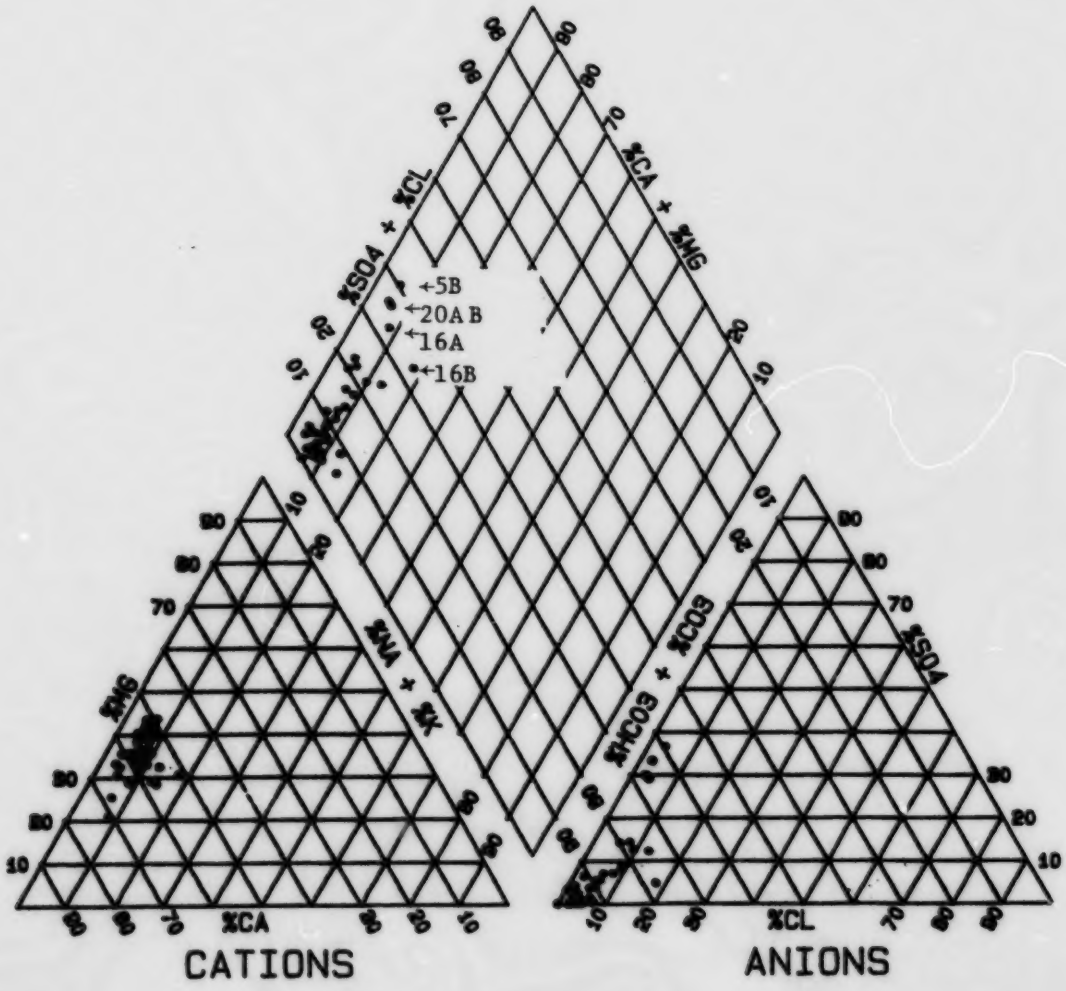


FIGURE 6

MAJOR ION CHEMISTRY
TBTGS ASH
JULY 26 1984
TYPE - WATER
ASH CELL AREA GROUNDWATER QUALITY - TBTGS - 1984



TBTGS ASH - SELECTED BOREHOLES

pH (Lab) vs TIME

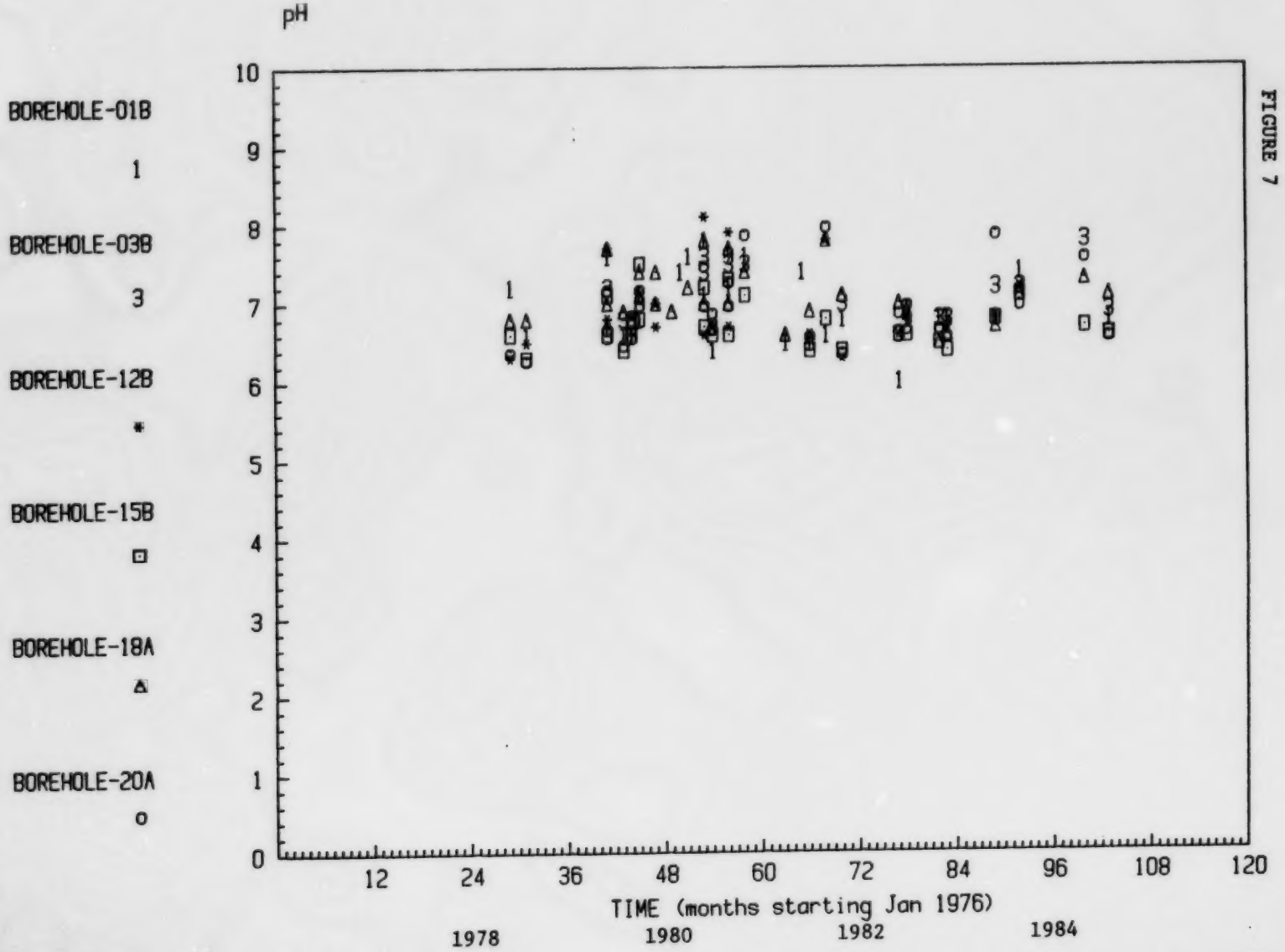


FIGURE 7

TBTGS ASH - SELECTED BOREHOLES

HCO3 ALKALINITY (LAB) vs TIME

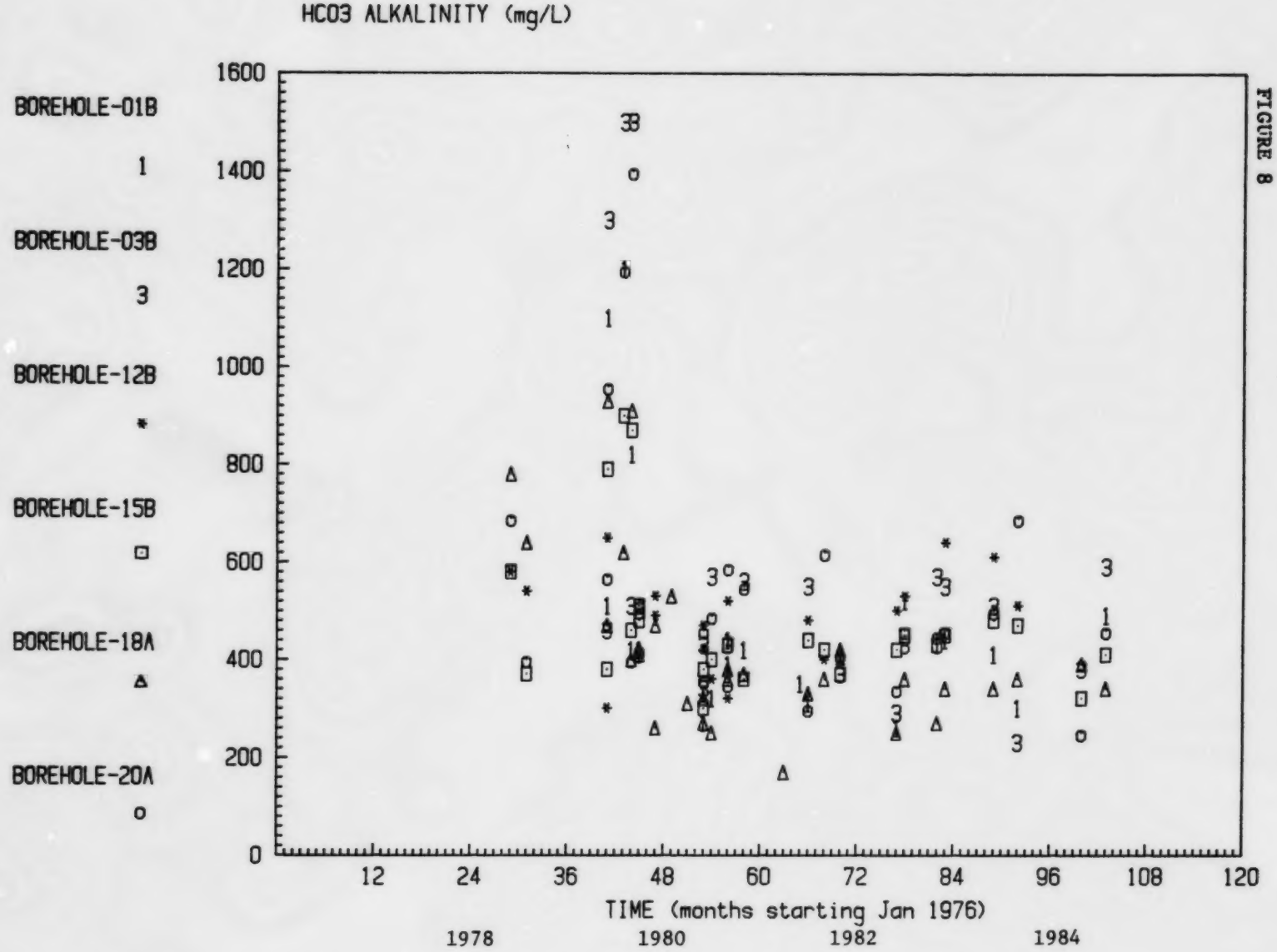


FIGURE 8

TBTGS ASH - SELECTED BOREHOLES

SULPHATE vs TIME

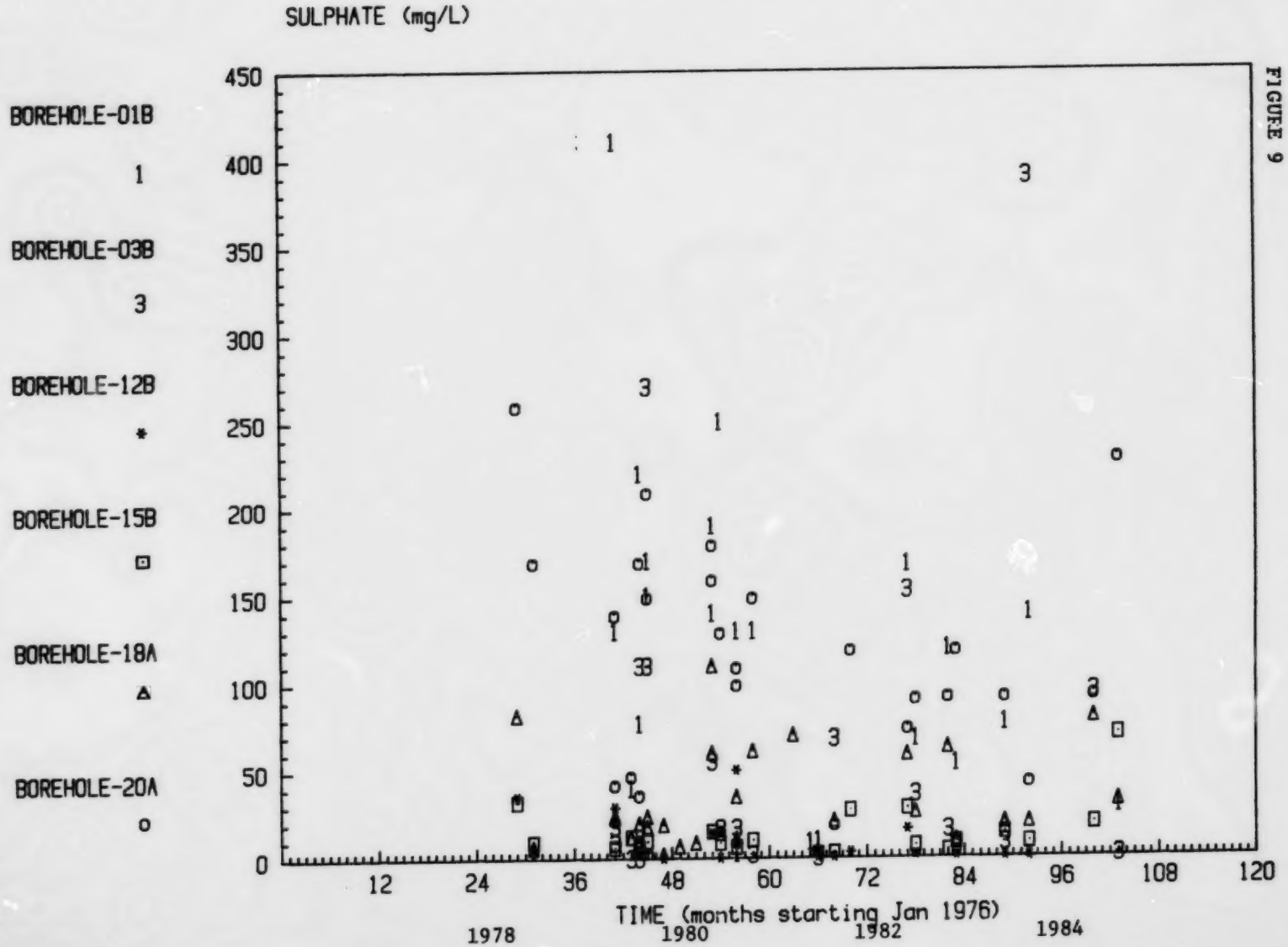


FIGURE 9

TBTGS ASH - SELECTED BOREHOLES

SODIUM vs TIME

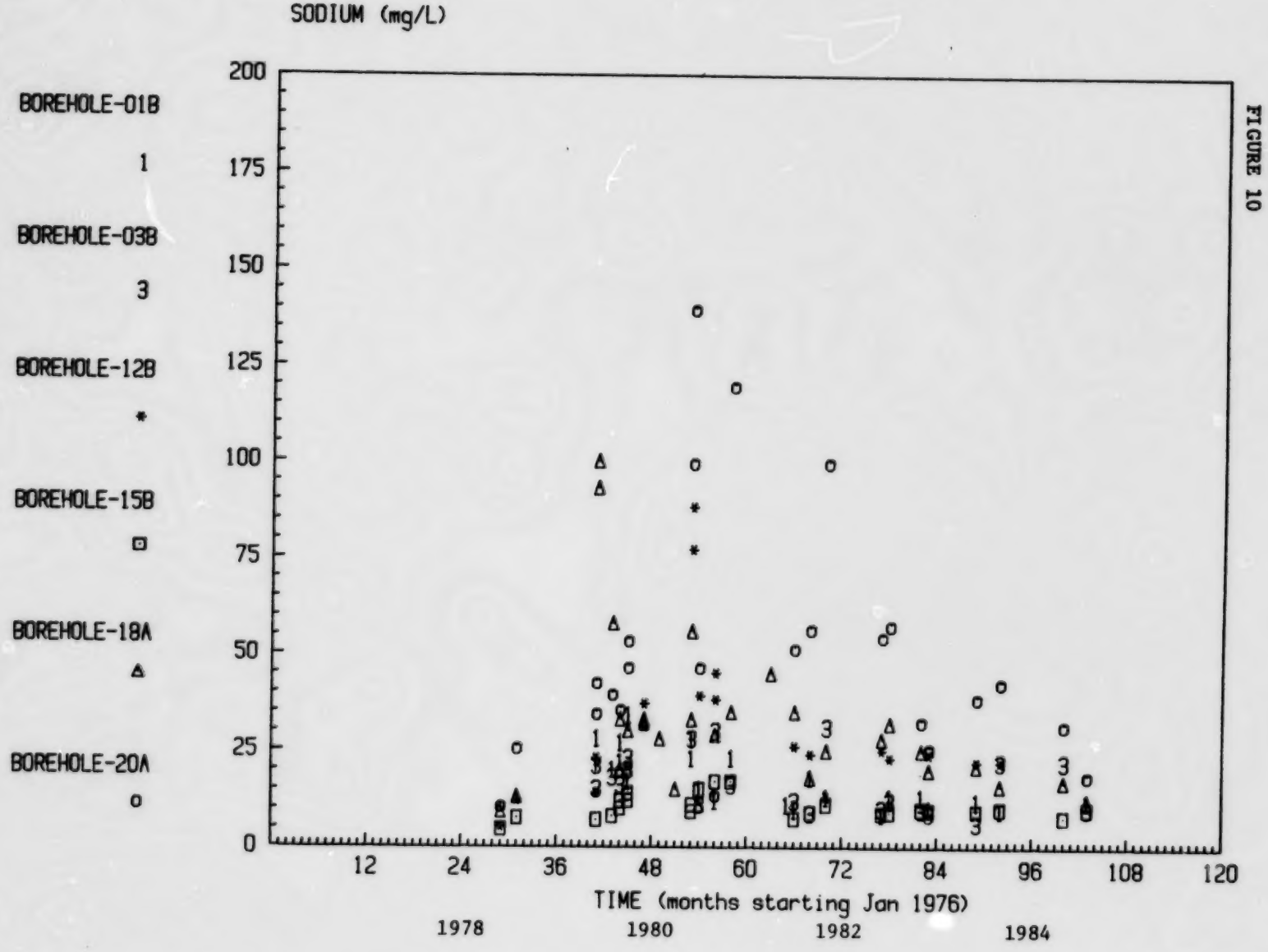


FIGURE 10

TBTGS ASH - SELECTED BOREHOLES

MAGNESIUM vs TIME

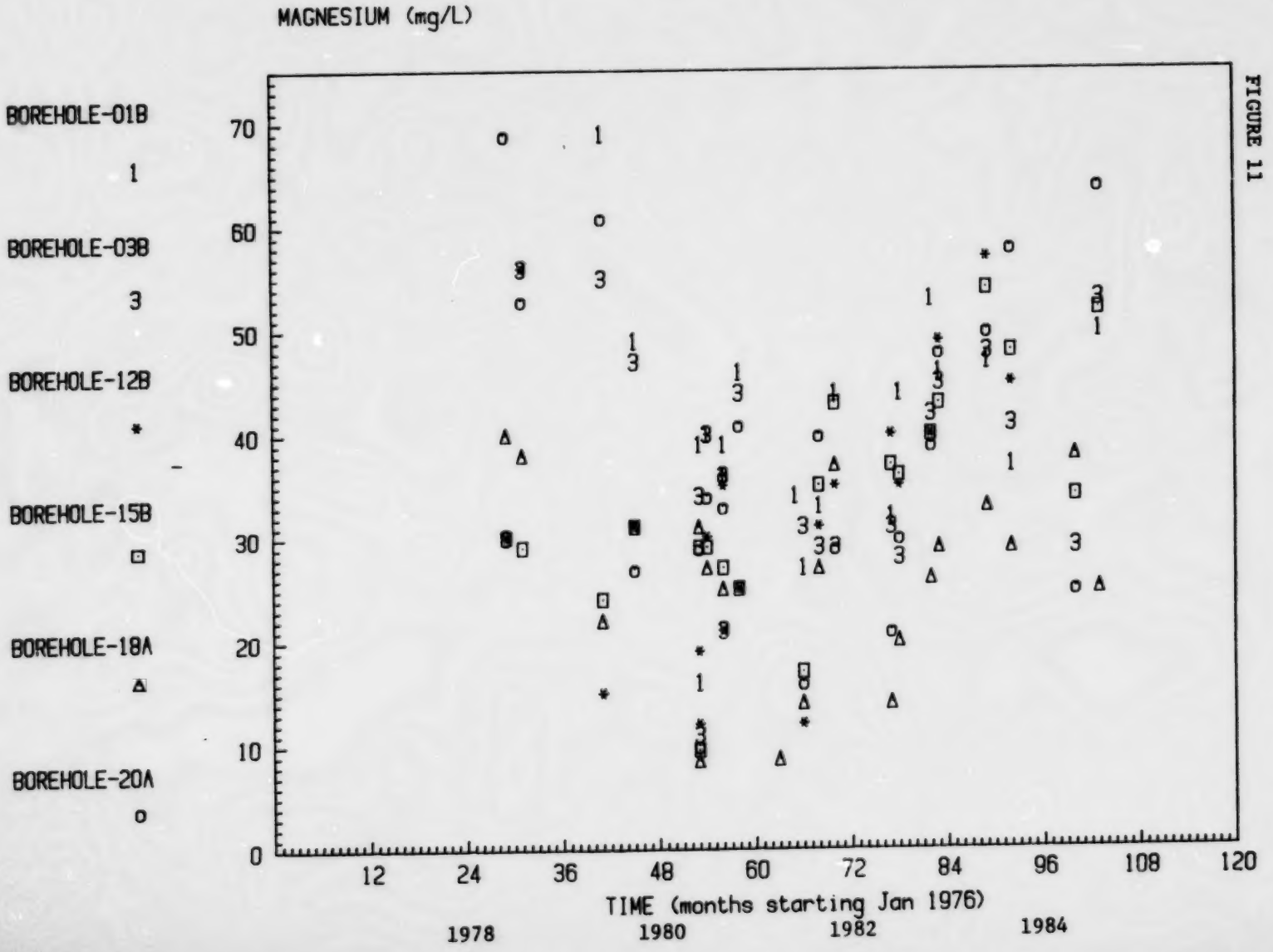


FIGURE 11

TBTGS ASH - SELECTED BOREHOLES

STRONTIUM vs TIME

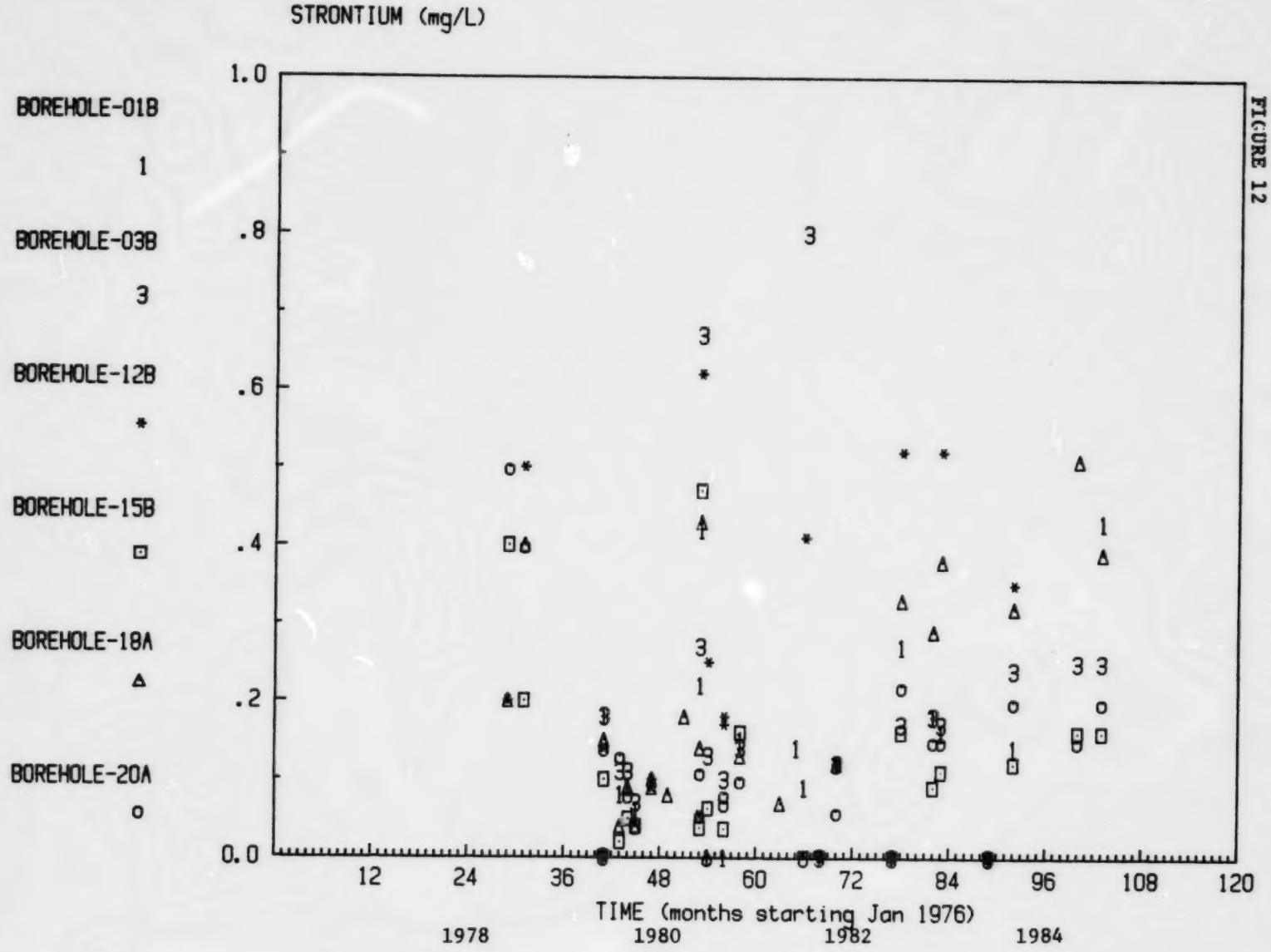


FIGURE 12

TBTGS ASH - SELECTED BOREHOLES

BORON vs TIME

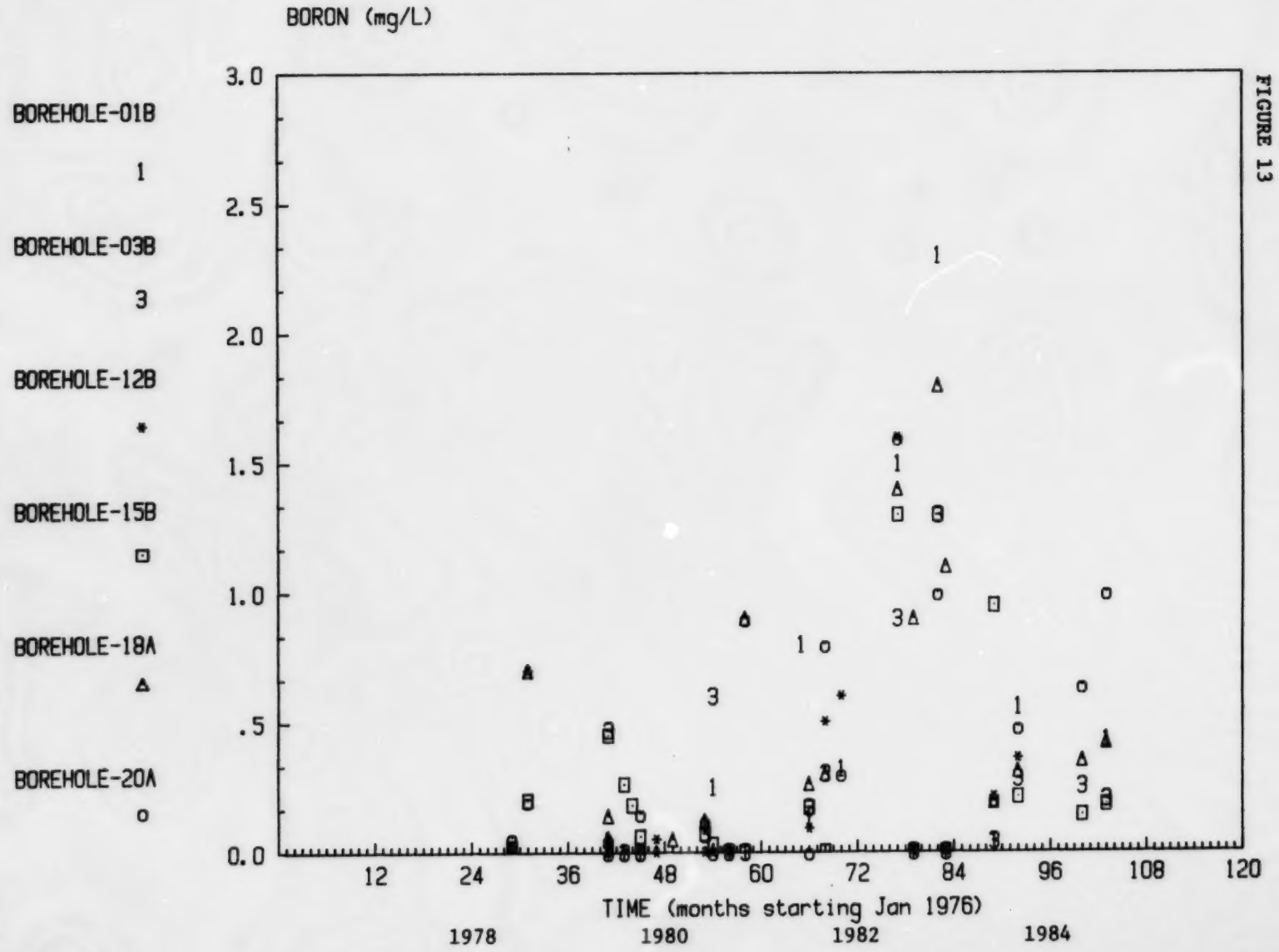


FIGURE 13

The sulphate vs Time plot (Figure 9) also contains many instances where there were elevated values in piezometers 1B, 3B and 20A but these do not strongly correlate with the incidences of high alkalinity and they do not show any consistent temporal pattern. As was mentioned previously, sulphate levels can be sharply changed by local biological activity in the groundwater and this is the probable cause of some of the extreme values which were observed.

Piezometers which often had elevated Na values (see Figure 10) were 20A and 18A (sometimes 12B). These temporally inconsistent increases in Na levels do not correlate with any of the other analyte increases and they can only be justified by considering them to be indicative of location specific natural variations.

Careful consideration of the plots of the other analytes confirms the findings that there are no significant temporal trends, no correlations of high values and hence, no evidence of groundwater contamination by ash leachate.

STATISTICAL ANALYSIS

The Statistics and Reliability Unit of Operations Research was contracted to perform an analysis of variance (ANOVA) on the chemical analysis data from the ash disposal area at TBTGS. The results of that analysis are detailed in report N85-1-K which is appended as Appendix D. The figures and tables referred to in this section are from Appendix D.

The purpose of this section is to:

1) provide a background to the statistical analysis
2) rationalize some of the steps which were required in the course of the statistical analysis
3) summarize the important statistical findings
4) relate the findings to a consistent set of observations and plans for the particular site.

1. Background

Before the ANOVA was initiated several variables were identified:

TYPE OF LABORATORY
LOCATION
STRATA
CHEMICAL SPECIES / ANALYTE
TIME

There were three laboratories involved in data collection since the beginning of the groundwater monitoring: London Monenco Ltd. (1976-79, pre-operational phase); TBTGS laboratory (also

designated as FIELD) and the Analytic Services Section laboratory at Research Division (LAB) were both involved after 1979.

When the groundwater monitoring project was initiated there was an arbitrary decision to divide the study into pre-operational (before 1981) and post-operational. This division of the data set was not made as the resultant sets would have been too small to carry out appropriate statistics especially considering the other variables which had to be carried in the analysis. Besides, any trend which would justify the operational period divisions should have been apparent in the grouped data.

Each location has at least two piezometers (piezometer 4 has 3) at different depths and in distinctly different soil strata. This was incorporated into the initial site design in order to assess the depth of pollutant infiltration and the extent of migration. The strata were considered to be a significant variable for consideration in addition to the piezometer nest location around the disposal cell.

Individual treatment of piezometers was not possible due to the severe restrictions placed upon a statistical analysis where the total number of observations for individual piezometers was not generally greater than 30 over the entire study. Individual trends in piezometer chemistry have been considered in separate time series plots for each analyte. Also, trends in piezometer chemistry have been implicitly incorporated into the overall analysis.

Time was considered the most important variable as the purpose of groundwater monitoring was to assess the changes in groundwater quality with time; in effect, to measure the influence of the presence of the deposited waste material on water quality.

There was a large number of values in the data set which were at analytical detection limits and which were reported as 'less than' values. These values were removed from the set in order to permit a more meaningful analysis. It must be kept in mind that the data set has been arbitrarily truncated and a consequent bias has been introduced. However, the bias is a conservative one, in that the average concentrations reported are higher. This favors environmental controls and limitations on the levels of all species. A tabulation of the analytes which have significant numbers of detection limit observations is shown in the summary statistics (Table II in Appendix D). In the course of the analysis it became clear that there was a number of arbitrary methods for dealing with large numbers of detection limit observations and the most conservative method seemed to be to ignore them in favor of higher values. An alternative would have been to assign the value of the detection limit as the actual value but even within one analyte these detection limit values

varied considerably from date to date.

Another important variable for the data analysis was the frequency of sampling and the number of analyses performed in the two Ontario Hydro laboratories. Analyses were performed about 6 times a year on a limited set of analytes, at TBTGS and more thorough analyses were completed at the LAB, twice per year. This was not explicitly dealt with but the effect of various frequencies of analysis precluded a proper time series analysis (by month) for many analytes.

2. Trends in 'Indicator' Ions -- Na, Mg, Sr, B

Due to their high relative abundances in flyash and different soil interactions and chemistries, Na, Mg, Sr and B were chosen as indicators of leachate production from the flyash disposed in the cell. The temporal trends in these ions are interesting in that they are basically indeterminate and they seem to indicate the levels of natural variability in the site which, to this date, is unaffected by the presence of ash.

Below is a summary of the yearly trends of the ln mean concentration of the indicator ions (taken from Table 5):

	ln of mean concentration for YEAR					
	1979	1980	1981	1982	1983	1984
B	-1.90	-1.74	-1.40	0.24	-2.03	0.52
Mg	3.45	3.23	3.32	3.47	3.60	-2.37
Na	2.81	2.91	2.81	2.72	2.73	2.75
Sr	-2.76	-1.98	-2.04	-1.79	-1.94	2.09

3. ANOVA Results and Discussion

The primary conclusions of the statistical study require some analysis which will rationalize them in terms of reasonable chemistry, site dynamics and natural variability.

a) Piezometer location is significant in the majority of cases. Although this is true and some of the variance in the data set can be explained by the difference in piezometer locations; an analysis of trends in the data reveals no essential trend in the chemistry which could be explained by hydrogeology or by ash placement within the disposal area.

b) **Strata is significant in less than one half of the species though significant interaction warrants caution in accepting this solution for some species.**
It is expected that there would be a very strong coupling of piezometers within a particular nest and the fact that this does not happen to the expected degree indicates substantial natural site variations (some of which are biological in nature).

c) **Testing site had a significant influence for the majority of species.**
The fact that 3 laboratories were involved in analyses contributed to the variance within the data set. Even when LMC data was deleted, there was a difference between the FIELD and LAB sets. There could be no further separation or deletion of data as the number of observations would have been reduced too significantly in some cases to warrant any further analysis.

d) **Date was significant for almost all species.**
The statistics leave no doubt that date is an important variable and that the mean values for analytes for each date were indeed different. However, it is the trend in year which is of importance in determining whether any change in the site has occurred. An analysis of the trend in the means of analytes by year shows no intelligible overall trend (see Table 5).

4. Conclusions

The conclusions which must be drawn from this are:

- the disposal site is not showing any leachate infiltration into the groundwater
- with the available data, there is no statistically significant difference between the pre-operational and post-operational periods
- the variations in analyte concentrations in the groundwater as a function of time reflect the natural variations which can be attributed to variations in site hydrogeochemistry
- no corrective measures are required at this time

5. Predictive Values

The table of summary statistics (Table II; Appendix D) provides an effective means to detect outliers. Early detection of

outliers is necessary in order to:
-implement resampling at the site
-provide a check on analytical accuracy
-provide first indications of changes in site chemistry (of primary importance)

It is more effective to individually (manually) determine the cause of outlying values because of the complexity of the site characteristics and other potential errors which can occur. A purely statistical and automatic procedure of outlier flagging is not necessary at this time given the potential expense involved in system development as well as the reduced level of commitment to the overall project.

RECOMMENDATIONS

1. The analytes which have rarely or never been detected (Be, I, Mo, Sb, Sn, Th and U) should not be measured in future unless there is substantial evidence that leachate is migrating through the groundwater regime. Hydroxide alkalinity is excluded from this list as it would be an important indicator of leachate formation.

2. The use of Piper diagrams should be continued to identify outliers in major ion chemistry.

3. A statistical reassessment should be performed only when the data set has increased significantly in size (5 years hence would be appropriate).

4. Maintenance of the same (or an increased) sampling frequency is recommended so that sufficient data from contiguous locations will be available for future statistical analyses.

5. Laboratory analyses (at Research Division) should be discontinued and should be replaced with at least an equivalent number of field analyses. Many of the extended list of analytes are below detection limit and they do not require measurement until significant changes are observed for other species. The variance caused by having two laboratories performing the analyses would also be eliminated.

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APPENDIX A

TBTGS GROUNDWATER AND LAKE* RELATIVE PIEZOMETER LEVELS 1979-1984

*(Lake Superior levels were obtained from Marine Environmental Data, Services Branch, Fisheries and Oceans, Ottawa)

1) RELATIVE PIEZOMETER AND LAKE LEVELS

THUNDER BAY TGS ASH CELL MONITORING PROGRAM

DATE OF PIEZOMETER READING

Borehole Number / Relative+ Level (m) / Date	790329	790405	790412	790419	790426	790503	790510	790517	790524
1A	1.19*	1.19*	1.19*	1.19*	1.51	1.49	1.53	1.52	1.45
1B	0.99	1.20	0.99	1.65	1.51	1.50	1.44	1.53	1.42
2A	1.19*	1.35*	1.07	1.35*	1.52	1.50	1.51	1.50	1.42
2B	1.30	1.45	1.04	1.35*	1.53	1.50	1.51	1.50	1.43
3A	-	1.31*	-	1.31*	1.51	1.46	1.40	1.48	1.37
3B	-	-	-	1.26*	1.49	1.44	1.43	1.47	1.39
4A	1.18*	1.21*	1.18*	1.21*	1.51	1.46	1.34	1.44	1.38
4B	1.32*	-	1.30*	1.33*	1.46	1.45	1.41	1.42	1.38
4C	-	-	-	1.17*	1.44	1.43	1.44	1.42	1.38
5A	1.23*	1.25*	1.25*	1.25*	1.26	1.26	1.21	1.20	1.17
5B	1.22*	1.16*	1.16*	1.18*	1.21	1.26	1.17	1.26	1.23
6A	1.06*	1.14*	1.11*	1.11*	1.16	1.21	1.13	1.21	1.19
6B	0.99*	1.17*	1.13*	1.14*	1.19	1.19	1.23	1.21	1.19
7A	-	0.98*	0.94*	0.96*	1.16	1.15	1.17	1.15	1.11
7B	1.01*	1.01*	0.94*	0.96*	1.16	1.15	1.15	1.16	1.12
8A	-	1.07*	-	1.07*	1.11	1.11	1.02	1.11	1.09
8B	-	1.06*	-	1.06*	1.08	1.08	1.02	1.09	1.09
9A	0.90	-	-	0.89	1.25	1.22	1.23	1.02	1.07
9B	-	-	-	0.73*	1.19	1.19	1.19	0.97	0.99
10A	-	1.00	-	0.90*	1.23	1.20	1.21	1.15	1.15
10B	-	-	-	0.94*	1.26	1.22	1.03	1.14	1.14
11A	-	-	-	0.91*	1.19	1.19	1.27	1.19	1.17
11B	-	-	-	0.87*	1.18	1.18	1.14	1.18	1.16
12A	0.93*	-	-	0.85*	0.88*	1.11	1.09	1.16	1.16
12B	1.38*	-	-	0.93*	0.87*	-	1.29	1.17	1.18
13A	-	1.20*	0.77*	1.02*	0.95	1.23	1.14	1.20	1.18
13B	-	1.51*	1.51*	1.08*	1.20	1.20	1.04	1.18	1.15
14A	-	-	-	-	-	-	-	-	-
14B	-	-	-	-	-	-	-	-	-
15A	0.94	0.84	0.86	0.84	1.24	1.24	1.01	1.24	1.24
15B	0.95	1.01	0.86	1.34*	1.21	1.23	1.03	1.21	1.21
16A	1.03*	1.04*	1.02*	1.27	1.22	1.27	1.21	1.30	1.23
16B	1.05	1.14	1.00*	1.14*	1.31	1.24	1.20	1.25	1.19
18A	1.03	1.13	0.95	1.38*	1.36	1.36	1.24	1.38	1.33
18B	1.02	1.11	0.95	1.44*	1.36	1.37	1.35	1.37	1.33
19A	0.96	1.20	0.70	1.41	1.33	1.33	1.43	1.33	1.28
19B	1.03	1.28	0.67	1.41	1.33	1.33	1.40	1.34	1.29
20A	0.81	0.94	0.72	1.44	1.44	1.42	1.38	1.43	1.42
20B	0.79	0.92	0.71	1.43	1.40	1.40	1.36	1.43	1.41
≠ Relative Lake Level	0.01	0.00	0.05	0.06	0.12	0.14	0.22	0.31	0.30

* denotes Dry or Frozen

+Water Table Level above 182.83 m reference elevation (Av shoreline elevation)

≠ Lake level above 182.88 m

THUNDER BAY TGS ASH CELL MONITORING PROGRAM

DATE OF PIEZOMETER READING

Borehole Number \ Relative+ Level (m) / Date	790531	790607	790614	790621	790628	790705	790712	790719	790726
1A	1.34	1.34	1.35	1.34	1.34	1.16	1.09	0.86	0.83
1B	1.32	1.32	1.32	1.32	1.30	1.32	1.07	0.84	0.79
2A	1.35	1.35	1.35	1.32	1.30	1.14	0.94	0.74	0.79
2B	1.35	1.35	1.35	1.32	1.30	1.15	0.92	0.71	0.79
3A	1.31	1.31	1.32	1.31	1.28	1.46	1.16	1.08	1.13
3B	1.31	1.31	1.33	1.31	1.29	1.26	1.16	1.09	1.14
4A	1.31	1.33	1.33	1.33	1.28	1.23	1.18	1.08	1.10
4B	1.30	1.30	1.30	1.29	1.23	1.25	1.13	1.05	1.07
4C	1.33	1.33	1.35	1.33	1.28	1.25	1.17	1.07	1.10
5A	1.14	1.14	1.12	1.12	1.09	1.09	1.02	0.92	0.97
5B	1.18	1.18	1.16	1.16	1.13	1.16	1.06	0.98	0.98
6A	1.11	1.11	1.10	1.11	1.09	1.09	0.96	0.86	0.88
6B	1.14	1.14	1.12	1.12	1.09	1.07	0.96	0.89	0.92
7A	1.08	1.11	1.08	1.08	1.06	1.01	0.91	0.85	0.86
7B	1.08	1.08	1.06	1.06	1.03	1.03	0.93	0.85	0.85
8A	1.06	1.07	1.04	1.04	1.02	1.02	0.89	0.79	0.81
8B	1.04	1.06	1.06	1.06	1.03	0.71	0.90	0.80	0.80
9A	0.71	1.04	1.04	1.04	1.01	0.97	0.92	0.89	0.92
9B	0.96	0.96	0.98	0.96	0.91	0.91	0.83	0.81	0.83
10A	1.13	1.13	1.13	1.13	1.10	1.05	1.00	0.97	0.97
10B	1.12	1.12	1.09	1.12	1.09	1.04	0.99	0.94	0.97
11A	1.09	1.11	1.09	1.06	1.06	0.98	0.98	0.93	0.96
11B	1.08	1.08	1.05	1.05	1.05	0.97	0.95	0.92	0.92
12A	1.13	1.11	1.13	1.13	1.08	-	-	-	-
12B	1.13	1.15	1.15	1.15	1.13	-	-	-	-
13A	1.12	1.12	1.12	1.12	1.12	1.10	1.03	1.00	1.00
13B	1.15	1.18	1.15	1.15	1.15	1.10	1.05	1.03	1.03
14A	-	-	-	-	Destroyed		-	-	-
14B	-	-	-	-			-	-	-
15A	1.09	1.09	1.09	1.09	1.07	1.09	1.04	0.86	0.92
15B	1.09	1.11	1.02	1.09	1.06	1.11	0.96	0.89	0.91
16A	1.17	1.17	1.17	1.17	1.14	1.12	0.86	0.86	0.89
16B	1.11	1.13	1.11	1.11	1.09	1.09	0.81	0.78	0.81
18A	1.23	1.28	1.25	1.28	1.28	0.92	1.00	0.86	0.92
18B	1.24	1.26	1.26	1.26	1.24	1.37	0.99	0.76	0.93
19A	1.13	1.31	1.13	1.31	1.10	0.93	0.75	0.62	0.70
19B	1.23	1.31	1.23	1.33	1.10	0.90	0.75	0.64	0.72
20A	1.37	1.37	1.36	1.34	1.32	1.17	1.17	0.96	0.96
20B	1.43	1.43	1.42	1.43	1.35	1.30	1.15	0.95	0.97
≠ Relative Lake Level	0.33	0.36	0.43	0.44	0.44	0.44	0.42	0.43	0.43

* denotes Dry or Frozen

+Water Table Level above 182.83 m reference elevation (Av. shoreline elevation)

≠ Lake level above 182.88 m

THUNDER BAY TGS ASH CELL MONITORING PROGRAM

DATE OF PIEZOMETER READING

Borehole Number \ Relative+ Level (m) / Date	790802	790809	790816	790824	790830	790906	790913	790920	790927
1A	0.78	0.59	0.49	0.64	0.58	0.78	0.88	0.78	0.55
1B	0.71	0.64	0.55	0.51	0.51	0.74	0.87	0.74	0.54
2A	0.74	0.50	0.41	0.58	0.61	0.89	0.97	0.86	0.58
2B	0.74	0.48	0.48	0.48	0.51	0.89	0.97	0.87	0.65
3A	1.11	0.88	0.75	0.96	0.98	1.16	1.16	1.11	0.91
3B	1.11	0.90	0.77	0.97	0.98	1.14	1.16	1.11	0.93
4A	1.08	0.95	0.86	0.95	0.98	1.10	1.13	1.13	1.03
4B	1.05	0.96	0.87	0.97	1.00	1.10	1.15	1.10	1.01
4C	1.10	0.95	0.86	0.95	0.97	1.10	1.13	1.10	1.00
5A	0.94	0.84	0.75	0.90	0.91	1.02	1.04	1.04	0.97
5B	0.98	0.90	0.83	0.98	1.16	1.08	1.31	1.10	1.02
6A	0.88	0.74	0.83	0.85	0.88	0.98	1.03	1.03	0.91
6B	0.89	0.74	0.80	0.85	0.97	1.14	1.04	1.04	0.94
7A	0.88	0.70	0.78	0.78	0.81	0.91	0.93	0.93	0.83
7B	0.86	0.70	0.77	0.78	0.81	0.91	0.96	0.91	0.81
8A	0.81	0.56	0.43	0.71	0.77	0.89	0.92	0.89	0.79
8B	0.80	0.57	0.49	0.73	0.77	0.88	0.93	0.90	0.77
9A	0.89	0.80	0.74	0.84	0.81	0.89	0.89	0.89	0.84
9B	0.83	0.78	0.70	0.78	0.78	0.85	0.85	0.85	0.78
10A	0.97	0.99	0.91	0.97	0.95	1.00	1.02	1.00	0.94
10B	0.94	0.97	0.89	0.97	0.97	0.99	1.02	0.99	0.91
11A	0.96	0.99	0.95	0.97	0.96	1.01	1.01	1.01	0.91
11B	1.11	0.97	0.94	0.95	0.95	0.97	0.97	0.97	0.90
12A	- flooded could			0.97	-	-	-	-	-
12B	-	not reach		0.98	-	-	-	-	-
13A	0.97	0.97	0.90	0.96	0.95	1.00	1.00	1.00	0.95
13B	1.00	0.97	0.90	0.95	0.95	1.00	1.00	1.00	0.95
14A	-	-	-		-	-	-	-	-
14B	-	-	destroyed		-	-	-	-	-
15A	0.89	0.80	0.77	0.86	0.81	0.94	0.99	0.94	0.79
15B	0.89	0.81	0.73	0.87	0.83	0.96	0.99	0.96	0.81
16A	0.86	0.69	0.69	0.60	0.63	0.86	0.94	0.84	0.66
16B	0.81	0.62	0.39	0.68	0.60	0.83	0.88	0.81	0.60
18A	0.92	0.64	0.57	0.49	0.72	0.95	1.02	0.90	0.62
18B	0.93	0.59	0.53	0.53	0.55	0.96	1.01	0.88	0.78
19A	0.67	0.48	0.43	0.41	0.39	0.62	0.72	0.60	0.47
19B	0.62	0.52	0.48	0.51	0.49	0.70	0.77	0.62	0.49
20A	0.91	0.66	0.58	0.71	0.71	0.96	1.06	0.96	0.71
20B	0.89	0.63	0.54	0.72	0.69	0.97	1.08		0.72
≠ Relative Lake Level	0.45	0.45	0.43	0.41	0.39	0.40	0.42	0.39	0.38

* denotes Dry or Frozen

+ Water Table Level above 182.83 m reference elevation (Av. shoreline elevation)

≠ Lake level above 182.88 m

THUNDER BAY TGS ASH CELL MONITORING PROGRAM

DATE OF PIEZOMETER READING

Borehole Number \ Date (Relative+ Level (m))	791002	791012	791018	791025	791101	791109	791115	791122	791129
1A	0.70	0.70	0.60	1.04					
1B	0.64	0.66	0.56	1.02					
2A	0.78	0.81	0.68	1.11	1.25	1.21	1.19	1.19	1.14
2B	0.76	0.79	0.66	1.12	1.25	1.22	1.19	1.19	1.14
3A	1.03	1.06	0.98	1.21					
3B	1.03	1.06	1.11	1.16					
4A	1.08	1.11	1.06	1.20					
4B	1.07	1.10	1.02	1.18					
4C	1.07	1.10	1.07	1.17					
5A	1.02	1.02	0.99	1.09					
5B	1.05	1.05	1.00	1.10					
6A	1.04	0.94	1.04	1.06	1.05	1.03	1.03	1.03	1.02
6B	0.99	1.02	0.99	1.07	1.07	1.04	1.03	1.04	1.02
7A	0.88	0.91	0.91	1.01					
7B	0.88	0.91	0.88	0.98					
8A	0.87	0.87	0.84	0.97					
8B	0.85	0.85	0.85	0.98					
9A	0.89	0.89	0.87	0.91					
9B	0.81	0.81	0.81	0.83					
10A	0.92	0.92	0.92	0.97					
10B	0.91	0.91	0.89	0.97					
11A	0.92	0.92	0.91	0.92	0.98	0.98	0.96	0.96	0.96
11B	0.90	0.90	0.87	0.92	0.97	0.97	0.95	0.95	0.95
12A	flooded could	0.95	0.93	0.98	-	1.03	0.99	1.00	1.06
12B	not reach	0.98	0.98	1.00	-	1.05	1.01	1.01	1.02
13A	0.92	0.95	0.92	1.00					
13B	0.97	1.00	0.95	1.02					
14A	-	-		-					
14B	-	destroyed		-					
15A	0.84	0.86	0.81	0.94					
15B	0.88	0.88	0.83	0.99					
16A	0.76	0.74	0.74	0.99					
16B	0.73	0.75	0.68	0.93					
18A	0.59	0.82	0.72	1.10	1.18	1.15	1.00	1.08	1.01
18B	0.73	0.60	0.65	1.11	1.19	1.16	0.99	1.09	1.04
19A	0.52	0.57	0.57	0.93	1.19	1.08	0.95	1.08	1.01
19B	0.52	0.57	0.57	0.98	1.18	1.08	0.95	1.08	0.99
20A	0.89	0.89	0.76	1.16					
20B	0.89	0.89	0.77	1.15					
≠ Relative Lake Level	0.37	0.27	0.33	0.37	0.43	0.34	0.33	0.31	0.28

* denotes Dry or Frozen

+ Water Table Level above 182.83 m reference elevation (Av. shoreline elevation)

≠ Lake level above 182.88 m

THUNDER BAY TGS ASH CELL MONITORING PROGRAM

DATE OF PIEZOMETER READING

Date	791205	791213	791220	791228					
Borehole Number \ Relative+ Level (m)									
1A									
1B									
2A	1.04	1.13	0.76	0.73					
2B	1.05	1.14	0.78	0.73					
3A									
3B									
4A									
4B									
4C									
5A									
5B									
6A	0.99	0.99	0.91	0.88					
6B	1.01	1.02	0.92	0.91					
7A									
7B									
8A									
8B									
9A									
9B									
10A									
10B									
11A	0.95	1.02	1.02	1.02					
11B	0.95	0.95	0.95	0.95					
12A	0.98	0.89	0.88	0.85					
12B	0.99	0.95	0.94	0.90					
13A									
13B									
14A									
14B									
15A									
15B									
16A									
16B									
18A	0.95	0.84	0.76	0.76					
18B	0.99	0.89	0.81	0.81					
19A	0.92	0.78	0.70	0.68					
19B	0.91	0.82	0.75	0.75					
20A									
20B									
≠ Relative Lake Level	0.28	0.28	0.29	0.21					

* denotes Dry or Frozen

+ Water Table Level above 182.83 m reference elevation (Av. shoreline elevation)

≠ Lake level above 182.88 m

TABLE 2

ASH CELL GROUNDWATER MONITORING PROGRAM - 1980
THUNDER BAY TGS EXTENSION

2 - RELATIVE PIEZOMETER AND LAKE WATER LEVELS - 1980
(Relative to Average Shoreline Level of 182.88 m)

Piezometer Identification	RELATIVE WATER LEVELS IN PIEZOMETERS (m) DATES MEASUREMENTS TAKEN - 1980																																		
	Jan 4	Jan 10	Jan 15	Jan 24	Jan 31	Feb 7	Feb 14	Feb 21	Mar 14	Mar 20	Mar 27	Apr 3	Apr 10	Apr 24	May 6	May 21	Jun 10	Jun 27	Jul 10	Jul 28	Aug 6	Aug 11	Aug 14	Aug 27	Sep 10	Sep 25	Oct 22	Nov 5	Dec 8	Dec 30
1A	-	-	-	-	-	-	-	-	-	-	-	-	-	1.16	1.11	0.98	1.30	0.76	0.86	1.16	0.95	0.81	0.84	0.75	1.16	1.26	1.17	1.13	-	-
1B	-	-	-	-	-	-	-	-	-	-	-	-	1.31	1.38	1.16	0.99	1.02	0.75	0.93	1.13	0.91	0.78	0.81	0.70	1.15	1.01	1.17	1.14	-	-
2A	0.32	0.27	0.27	0.24	0.17	0.03	-0.03	-0.03	-0.16	-0.14	0.32	1.23	-	1.11	1.03	1.01	1.02	0.72	0.93	1.06	1.19	1.09	1.03	0.97	1.23	1.29	1.28	1.28	1.23	0.78
2B	0.35	0.27	0.26	0.26	0.20	0.07	-0.01	-0.03	-0.08	0.08	0.45	1.26	-	1.11	1.07	1.08	1.01	0.70	0.70	1.04	1.18	1.13	1.05	0.98	1.35	1.38	1.37	1.30	1.25	0.87
3A	-	-	-	-	-	-	-	-	-	-	-	-	-	1.41	1.40	1.27	1.30	1.07	1.17	1.35	1.26	1.19	1.21	1.21	1.36	1.39	1.36	1.34	-	-
3B	-	-	-	-	-	-	-	-	-	-	-	-	-	1.42	1.39	1.30	1.31	1.08	1.19	1.32	1.15	1.12	1.10	1.17	1.33	1.39	1.33	1.29	-	-
4A	-	-	-	-	-	-	-	-	-	-	-	-	-	1.41	1.41	1.26	1.29	1.16	1.31	1.31	1.27	1.22	1.27	1.20	1.35	1.36	1.34	1.32	-	-
4B	-	-	-	-	-	-	-	-	-	-	-	-	-	1.35	1.35	1.25	1.25	1.13	1.22	1.30	1.27	1.21	1.27	1.16	1.38	1.37	1.34	1.26	-	-
4C	-	-	-	-	-	-	-	-	-	-	-	-	-	1.45	1.36	1.27	1.32	1.12	1.22	1.27	1.21	1.16	1.19	1.21	1.37	1.41	1.38	1.30	-	-
5A	-	-	-	-	-	-	-	-	-	-	-	-	1.23	1.21	1.22	1.19	1.19	1.07	1.13	1.21	1.17	1.10	1.29	1.12	1.24	1.24	1.10	1.26	-	-
5B	-	-	-	-	-	-	-	-	-	-	-	-	1.20	1.20	1.19	1.12	1.17	1.07	1.12	1.20	1.15	1.03	1.12	1.05	1.18	1.17	1.16	1.16	-	-
6A	0.83	0.80	0.79	0.80	0.69	0.36	0.48	0.44	0.26	0.26	0.60	1.27	1.17	1.16	1.13	1.09	1.12	1.03	1.07	1.12	1.10	1.05	1.10	1.00	1.20	1.15	1.13	1.11	1.16	0.91
6B	0.86	0.81	0.79	0.81	0.69	0.36	0.49	0.44	0.23	0.25	0.23	1.19	1.17	1.16	1.16	1.12	1.14	1.04	1.06	1.12	1.10	1.05	1.11	1.00	1.20	1.23	1.16	1.13	1.14	P
7A	-	-	-	-	-	-	-	-	-	-	-	-	1.15	1.07	1.06	1.02	1.07	0.98	0.97	1.07	1.03	0.93	1.01	0.96	1.11	1.11	1.09	1.06	-	-
7B	-	-	-	-	-	-	-	-	-	-	-	-	0.98	1.08	1.07	1.03	1.07	0.97	1.00	1.09	1.04	0.98	1.06	0.98	1.08	1.12	1.08	1.06	-	-
8A	-	-	-	-	-	-	-	-	-	-	-	-	0.98	1.11	1.03	1.03	1.10	0.92	0.96	0.91	1.04	0.98	1.06	0.93	1.09	1.12	1.11	1.08	-	-
8B	-	-	-	-	-	-	-	-	-	-	-	-	1.12	1.07	0.99	1.20	1.02	0.93	0.94	0.88	1.03	1.00	1.08	0.95	1.09	1.12	1.10	1.06	-	-
9A	-	-	-	-	-	-	-	-	-	-	-	-	0.81	0.94	0.82	0.90	0.92	0.96	1.01	0.98	0.91	0.86	0.96	0.86	0.94	C.96	0.90	0.93	-	-
9B	-	-	-	-	-	-	-	-	-	-	-	-	0.79	0.94	0.89	0.88	0.97	0.96	0.94	0.98	0.84	0.77	0.86	0.84	0.98	1.19	0.89	0.93	-	-
10A	-	-	-	-	-	-	-	-	-	-	-	-	-	1.12	1.08	1.02	1.07	0.97	0.98	1.09	1.08	1.03	1.06	0.95	1.08	1.06	1.09	1.03	-	-
10B	-	-	-	-	-	-	-	-	-	-	-	-	-	1.12	0.99	0.99	1.03	0.97	0.97	1.10	1.04	1.03	1.03	0.95	1.05	1.07	1.04	1.05	-	-
11A	0.89	0.92	0.89	0.89	0.74	0.49	0.46	0.39	0.24	0.33	0.67	1.12	1.10	1.12	1.05	1.00	1.11	0.98	0.74	0.89	0.88	0.83	0.88	0.81	1.03	1.03	1.03	1.03	0.98	P
11B	0.90	0.92	0.90	0.90	0.74	0.47	0.59	0.37	0.26	0.38	0.64	1.10	1.10	1.12	1.12	1.00	1.04	0.99	0.74	0.78	0.82	0.75	0.83	0.84	1.02	1.03	1.10	1.04	1.01	P
12A	P(2)	P	P	P	P	P 0.93	0.93	0.98	P 0.98	P 0.98	0.98	CUV(2)	-		1.08		1.02	0.98	0.93	1.00	1.02	0.93	1.02	-	-	-	-	-	1.10	P
12B	P	P	P	P	P	P 0.99	0.98	1.00	P 1.03	P 1.03	1.03	CUV	-		1.16		1.11	1.02	0.95	1.03	1.05	0.95	1.08	-	-	-	-	-	1.04	P
13A	-	-	-	-	-	-	-	-	-	-	-	-	0.91	1.09	1.05	1.03	1.04	0.90	0.95	1.05	0.92	0.90	1.02	0.97	1.07	1.11	1.03	1.02	-	-
13B	-	-	-	-	-	-	-	-	-	-	-	-	0.96	1.09	1.04	1.05	1.04	0.93	0.94	1.04	0.92	0.85	0.96	0.98	1.09	1.16	1.11	1.10	-	-
13A	-	-	-	-	-	-	-	-	-	-	-	-	1.01	1.16	0.74	0.77	1.09	0.86	0.96	1.09	0.83	0.63	0.96	0.83	1.09	1.10	1.08	1.08	-	-
13B	-	-	-	-	-	-	-	-	-	-	-	-	1.14	1.14	1.10	1.19	1.09	0.59	0.94	1.19	0.98	0.93	1.10	0.88	1.08	1.12	1.14	1.10	-	-
14A	-	-	-	-	-	-	-	-	-	-	-	-	1.21	1.18	1.16	1.09	1.14	0.91	0.86	1.11	0.94	0.86	0.91	0.79	1.11	1.19	1.16	1.14	-	-
14B	-	-	-	-	-	-	-	-	-	-	-	-	1.19	1.22	1.17	1.08	1.14	0.84	0.86	1.14	0.98	0.90	0.95	0.77	1.10	1.18	0.99	0.96	-	-
15A	0.83	-	0.85	0.86	0.75	0.60	0.33	0.33	0.23	0.24	0.58	1.27	1.27	1.26	1.10	1.13	1.14	0.96	0.91	1.19	0.88	0.83	0.97	0.87	1.08	1.21	1.21	1.19	1.15	0.95
15B	0.81	-	0.86	0.89	0.81	0.68	0.68	0.68	0.49	0.47	0.69	1.34	1.30	1.26	1.19	1.14	1.14	0.96	0.89	1.16	0.95	0.87	0.97	0.87	1.11	1.25	1.18	1.19	1.15	0.81
16A	0.79	-	0.85	0.86	0.67	0.60	0.36	0.36	0.28	0.31	0.55	1.40	1.36	1.31	1.27	1.16	1.12	1.05	0.69	0.92	0.86	0.53	0.58	0.55	1.03	1.26	1.22	1.16	1.12	0.73
16B	0.89	-	0.92	0.96	0.91	0.66	0.66	0.66	0.58	0.66	0.66	1.65	1.29	1.32	1.26	1.13	1.12	1.12	0.87	1.02	0.86	0.78	0.92	0.91	1.02	1.23	1.23	1.21	0.98	0.53
20A	-	-	-	-	-	-	-	-	-	-	-	-	1.30	1.34	1.30	1.27	1.28	0.86	0.78	1.18	1.09	1.06	0.81	0.89	1.22	1.31	1.34	1.32	-	-
20B	-	-	-	-	-	-	-	-	-	-	-	-	1.26	1.31	1.32	1.27	1.26	0.96	0.78	1.18	1.13	1.05	0.89	0.91	1.21	1.28	1.28	1.22	-	-
21A	-	-	-	-	-	-	-	-	-	-	-	-	1.23	1.19	1.21	1.01	1.08	0.67	0.52	0.62	0.55	0.48	0.52	0.37	1.04	1.09	0.96	1.16	-	-
21B	-	-	-	-	-	-	-	-	-	-	-	-	1.27	1.20	1.15	1.01	1.05	0.68	0.54	0.65	0.63	0.56	0.61	0.38	1.08	1.17	1.07	1.19	-	-
22A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.06	1.31	1.63	1.26	1.21	1.19	1.21	1.63	1.63	1.61	1.61	-	-
22B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.31	1.32	1.17	1.26	1.21	1.15	1.21	1.32	1.64	1.62	1.61	-	-
Lake Levels (1)	-	-	-	-	0.19	-	-	0.13	-	-	0.85	-	-	0.86	-	0.12	-	0.17	-	0.21	-	-	-	0.26	-	0.24	0.26	0.30	-	0.84

1. Relative Average Monthly Lake Levels, above 182.88 = reference level.

2. P = Frozen; CUV = piezometer cap under water.

A7

85-171

TABLE A11

PRE-OPERATIONAL ASH CELL GROUNDWATER QUALITY STUDY - 1981
THUNDER BAY TCR EXTENSION

RELATIVE PIEZOMETER AND LAKE WATER LEVELS - 1981
(Relative to Average Mean[illegible] Level of 182.88 m)

Piezometer Identification	Relative Water Levels in Piezometers (m) on Dates Measurements Were Taken																	
	(Values Based on June 1980 Reference Levels)						(Values Based on July 1981 Reference Levels)											
	Jan. 26/81	Feb. 24/81	Mar. 10/81	Mar. 17/81	Mar. 24/81	Apr. 15/81	Apr. 29/81	May 6/81	May 27/81	June/81	July 2/81	July 24/81	Aug. 6/81	Aug. 25/81	Sept. 4/81	Oct. 26/81	Nov. 27/81	Dec. 08/81
1							1.00	1.33	1.30		0.75	1.30	0.60	0.27	0.46	0.92		
2	1.52	0.67	0.66	0.87	0.96	1.47	1.21	1.31	1.26		0.84	1.29	0.56	0.34	0.43	0.95		
3	1.54	0.68	0.60	0.89	1.01	1.49	1.29	1.37	1.31		0.87	1.05	0.81	0.38	0.45	0.85	0.84	0.89
4							1.35	1.40	1.34		0.87	1.07	0.81	0.37	0.51	0.84	0.88	0.64
5							1.41	1.43	1.35		0.85	0.92	0.80	0.39	0.61	1.06		
6							1.41	1.42	1.36		0.86	0.86	0.93	0.47	0.76	1.12		
7							1.29	0.90	1.27		0.97	1.09	0.92	0.56	0.79	1.08		
8							1.25	1.31	1.27		0.98	1.12	0.85	0.55	0.72	1.01		
9							1.30	1.03	1.28		1.02	1.06	0.94	0.54	0.83	0.99		
10							1.26	1.24	1.21		1.15	1.21	0.97	0.53	0.76	0.93		
11	1.35	1.10	1.20 (F)	1.20 (F)	1.19 (F)	1.33	1.21	1.26	1.22		1.04	1.08	1.00	0.55	0.78	0.98		
12	1.61 (F)	1.12	1.20 (F)	1.20 (F)	1.19 (F)	1.35	1.25	1.28	1.23		1.01	1.18	0.99	0.60	0.78	0.95	1.05	0.85
13							1.23	1.27	1.21		1.01	1.17	0.97	0.55	0.74	0.98	1.03	
14							1.02	1.02	0.95		0.89	0.91	0.81	0.42	0.70	0.87		
15							1.03	1.05	1.13		0.89	0.91	0.85	0.41	0.65	0.89		
16							1.15	1.13	1.09		0.89	0.94	0.86	0.38	0.61	0.94		
17							1.17	1.04	1.07		0.90	0.92	0.86	0.39	0.61	0.93		
18							0.83	0.84	0.82		0.73	0.80	0.59	0.30	0.50	0.84		
19			1.06 (F)				0.68	0.39	0.66		0.58	0.69	0.48	0.25	0.42	0.52		
20			1.00 (F)		1.10 (F)		1.04	1.05	1.03		0.62	0.62	0.87	0.74	0.80	0.76		
21	1.49 (F)	1.04 (F)	1.01 (F)		1.06 (F)		1.04	1.04	1.01		0.66	0.66	0.83	0.75	0.78	0.76		
22	1.49 (F)	1.03 (F)	1.02 (F)	1.05 (F)	1.03 (F)	1.19	1.07	1.15	1.08		0.98	0.78	0.93	0.81	0.86	0.90	0.93	0.88
23	1.52 (F)	1.11 (F)		1.03 (F)	1.04 (F)	1.23	1.08	1.14	1.10		0.98	0.88	0.93	0.80	0.77	0.90	0.94	0.86
24	1.57 (F)	1.10 (F)		1.10 (F)	1.08 (F)	*	*	1.03			0.93	0.73	1.02	0.91	M	0.96		F
25				1.13 (F)	1.10 (F)	*	*	1.08			0.89	0.84	1.04	0.95	M	0.98		0.92
26							1.09	0.48	1.05		0.87	1.05	0.87	0.66	0.83	0.81		
27							1.09	1.03	1.10		0.91	1.03	0.90	0.65	0.76	0.89		
28							1.01	1.00	1.04		0.90	0.91	0.87	0.43	0.62	0.78		
29							1.07	1.08	1.06		1.14	1.09	0.88	0.46	0.96	1.09		
30							1.14	1.21	1.18		1.01	0.97	0.90	0.39	0.75	0.85		
31	1.34 (F)	1.15 (F)	1.12	1.26	1.30	1.41	1.18	1.30	1.21		0.83	1.10	0.92	0.39	0.73	0.78		
32	1.65 (F)	1.32	1.18	1.28	1.43 (F)	1.33	1.19	1.25	1.20		0.92	0.84	0.86	0.25	0.49	0.98	0.95	0.49
33	1.60 (F)	1.07		1.25	1.35	1.32	1.22	1.23	1.12		1.14	0.95	0.74	0	0.51	0.71	0.95	0.49
34	1.46 (F)	0.91	0.93	1.11	1.21	1.30	1.16	1.25	1.13		0.88	1.05	0.45	0.13	0.20	0.48	0.70	0.41
35			0.91				1.14	1.15	1.14		0.73	1.08	0.30	0.26	0.28	0.41	0.69	0.49
36							1.33	1.33	1.30		0.50	1.04	0.98	0.34	0.36	0.77		
37							1.18	1.30	1.25		0.57	1.05	0.93	0.29	0.44	0.77		
38							1.04	1.07	0.99		0.83	0.72	0.52	0.06	0.34	0.78		
39							1.03	0.99	1.01		0.72	0.65	0.33	0.07	0.14	0.69		
40							**		1.57		0.88	1.06	1.12	0.57	0.81	1.15		
41							**		1.26		0.77	0.89	0.78	0.25	0.49	0.98		
Lake Levels (1)	0.00	-0.06			-0.05		0.05		0.13	0.12		0.25		0.23	0.16	0.14	0.08	0.04

(F) - Water frozen
* - Not enough to reach
** - Pipe stuck
M - Dry
N - Lost out
(1) - Relative Average Monthly Lake Levels (relative to 182.88 m)

TABLE III

ASH CELL GROUNDWATER MONITORING PROGRAM - 1982
THUNDER BAY TCS EXTENSION

RELATIVE PIEZOMETER AND LAKE WATER LEVELS - 1982
(Relative to Average Shoreline Level of 182.88 m)

Piezometer Identification	Relative Water Levels in Piezometers (m)															
	Dates Measurements Were Taken															
	Jan. 15/82	Feb. 19/82	Mar. 5/82	Mar. 19/82	Apr. 2/82	Apr. 16/82	May 14/82	June 25/82	July 23/82	Aug. 20/82	Sept 3/82	Sept 28/82	Oct. 13/82	Oct. 25/82	Nov. 8/82	Nov. 17/82
P78-1A							1.33	1.08	1.18	1.20	1.31	1.16	1.28	1.34	1.26	1.24
P78-1B							1.39	1.13	1.27	1.30	1.41	1.23	1.38	1.45	1.37	1.36
P78-2A	0.24	0.07	0.15	0.07	0.84	1.40	1.42	1.31	1.37	1.40	1.42	1.32	1.45	1.48	1.41	1.36
P78-2B	0.28	0.28	0.31	F	0.81	1.42	1.43	1.32	1.38	1.41	1.41	1.34	1.45	1.48	1.41	1.39
P78-3A							1.51	1.32	1.37	1.40	1.55	1.33	1.57	1.50	1.37	1.37
P78-3B							1.49	1.30	1.40	1.41	1.26	1.31	1.54	1.49	1.38	1.34
P78-4A							1.47	1.27	1.40	1.44	1.39	1.30	1.56	1.48	1.36	1.42
P78-4B							1.23	1.25	1.32	1.36	1.37	1.24	1.51	1.48	1.36	1.41
P78-4C							1.43	1.24	1.39	1.41	1.40	1.25	1.52	1.47	1.37	1.41
P78-5A							1.25	1.25	1.26	1.23	1.25	1.25	1.29	1.30	1.25	1.22
P78-5B							1.24	1.16	1.20	1.16	1.25	1.18	1.22	1.30	1.23	1.21
P78-6A	0.41	0.23	0.30	0.31	1.12	1.16F	1.26	1.11	1.22	1.17	1.21	1.13	1.23	1.28	1.23	1.17
P78-6B	0.48	0.23	0.32	0.22	1.11	1.17F	1.20	1.11	1.22	1.17	1.19	1.14	1.28	1.28	1.22	1.18
P78-7A							1.16	1.04	1.23	1.14	1.20	1.10	1.28	1.27	-	1.24
P78-7B							1.18	1.07	1.20	1.17	1.19	1.10	1.24	1.27	1.18	1.08
P78-8A							1.18	1.02	1.20	1.16	1.19	1.12	1.25	1.27	1.19	1.20
P78-8B							1.22	1.05	1.23	1.17	1.21	1.13	1.06	1.28	1.13	1.16
P78-9A							0.90	0.94	0.94	0.96	0.97	1.00	0.96	1.00	0.94	0.97
P78-9B							0.61	0.89	0.92	0.93	0.97	0.90	0.93	0.99	0.92	0.95
P78-10A							1.11	1.07	1.12	1.12	1.16	1.08	1.17	1.19	1.14	1.14
P78-10B							0.62	1.07	1.12	1.15	1.19	1.09	1.15	1.19	1.13	1.26
P78-11A	0.64	0.42	0.57	0.73	1.10	1.11F	1.15	1.04	1.11	1.13	1.18	1.07	1.14	1.19	1.13	1.15
P78-11B	F	0.34	0.60	0.72	1.08	1.16	1.19	1.04	1.11	1.12	1.16	1.06	1.14	1.19	1.14	1.14
P78-12A		F			0.85F	0.80F	1.08	1.04	1.09	-	-	-	-	1.16	-	1.14
P78-12B		0.02			0.95F	0.91F	1.28	1.06	1.11	-	-	-	-	1.16	-	1.15
P78-13A							1.02	1.07	1.11	1.16	1.16	1.08	1.17	1.18	1.13	1.17
P78-13B							0.87	1.10	1.15	1.20	1.19	1.12	1.21	1.19	-	1.13
P78-14A							-	-	-	-	-	-	-	-	-	-
P78-14B							-	-	-	-	-	-	-	-	-	-
P78-15A							1.19	1.03	1.10	1.16	1.23	1.09	1.20	1.25	1.72	1.13
P78-15B							1.17	1.10	1.29	1.24	1.24	1.14	1.26	1.26	1.17	1.20
P78-16A							1.29	1.14	1.12	1.30	1.32	1.20	1.31	1.32	1.26	1.14
P78-16B							1.29	1.14	1.35	1.25	1.29	1.21	1.37	1.31	1.25	1.18
P78-17A							-	-	-	-	-	-	-	-	-	-
P78-17B							-	-	-	-	-	-	-	-	-	-
P78-18A	0.40	0.24	0.31	0.28	1.32	1.36	1.39	1.20	1.30	1.32	1.41	1.25	1.34	1.36	1.32	1.31
P78-18B	F	F	F	F	1.37	1.37	1.37	1.23	1.30	1.30	1.36	1.26	1.23	1.36	1.23	1.31
P78-19A	0.32	0.21	0.21	0.23	1.26	1.42	1.43	1.48	1.18	1.25	1.29	1.18	1.34	1.31	1.19	1.21
P78-19B	F	F	F	F	1.22	1.43	1.40	1.39	1.17	1.27	1.30	1.19	1.33	1.30	1.28	1.21
P78-20A							1.42	1.08	1.42	1.39	1.43	1.36	1.41	1.42	1.39	1.41
P78-20B							1.43	1.07	1.41	1.39	1.44	1.36	1.44	1.42	1.35	1.40
P79-21A							1.16	1.08	-	1.28	1.18	1.12	1.22	1.19	1.18	1.15
P79-21B							1.16	1.08	-	1.10	1.16	1.14	1.19	1.19	1.18	1.20
P80-22A							1.43	1.41	-	1.50	1.44	1.41	1.57	1.45	1.44	1.28
P80-22B							1.49	1.42	-	1.69	1.41	1.42	1.53	1.50	1.45	1.63
Lake Level (1)	-0.07	-0.11	-0.14		-0.07		0.09	0.15	0.24	0.30		0.31		0.38	0.40	0.34 (Dec)

F = Water Frozen
(1) = Relative Average Monthly Lake Levels (relative to 182.88 m)

TABLE III

ASH CELL GROUNDWATER QUALITY STUDIES - 1983
THUNDER BAY TGS EXTENSION

RELATIVE PIEZOMETER AND LAKE WATER LEVELS - 1983
(Relative to Average Shoreline Level of 182.88 m)

Piezometer Identification	Relative Water Levels in Piezometers (m)				
	Dates Measurements Taken				
	May 4, 1983	June 24, 1983	Aug. 10, 1983	Sept 28, 1983	Oct 28, 1983
P78 1A	1.26	1.06	0.90	0.69	1.15
P78 1B	1.12	1.16	1.08	0.73	1.29
P78 2A	1.42	1.27	1.22	1.02	1.32
P78 2B	1.44	1.29	1.20	1.03	1.33
P78 3A	1.46	1.27	1.16	0.96	1.31
P78 3B	1.46	1.24	1.21	0.96	1.31
P78 4A	1.26	1.24	1.14	1.08	1.28
P78 4B	1.17	1.20	1.11	1.01	1.23
P78 4C	1.40	1.23	1.14	1.07	1.25
P78 5A	0.97	1.22	1.28	1.02	1.19
P78 5B	1.29	1.15	1.04	0.94	1.13
P78 6A	1.19	1.11	1.05	0.89	1.07
P78 6B	1.24	1.13	1.06	0.90	1.08
P78 7A	0.94	1.05	0.97	0.87	1.01
P78 7B	1.25	1.13	1.08	0.96	1.09
P78 8A	0.80	1.10	1.03	0.90	1.05
P78 8B	1.24	1.13	1.09	0.92	1.09
P78 9A	0.79	0.89	0.86	0.80	0.87
P78 9B	0.66	0.85	0.79	0.76	0.82
P78 10A	1.17	1.07	0.97	0.92	1.04
P78 10B	1.13	1.03	0.94	0.89	1.01
P78 11A	1.15	1.05	0.97	0.89	1.00
P78 11B	1.13	1.04	0.97	0.89	1.03
P78 12A	1.00	1.02	0.86	0.90	--
P78 12B	0.88	1.08	0.96	0.96	--
P78 13A	0.87	1.05	0.98	0.92	1.02
P78 13B	0.79	1.06	1.00	0.92	1.03
P78 14A	-	-	-	--	--
P78 14B	-	-	-	--	--
P78 15A	1.09	1.05	0.99	0.86	1.06
P78 15B	1.29	1.05	1.06	0.87	1.08
P78 16A	1.05	1.12	1.03	0.86	1.11
P78 16B	1.24	1.14	1.11	0.96	1.12
P78 17A	-	-	-	--	--
P78 17B	-	-	-	--	--
P78 18A	1.31	1.17	1.14	0.59	1.16
P78 18B	1.34	1.19	0.95	0.66	1.20
P78 19A	1.36	1.05	1.01	0.42	1.12
P78 19B	1.33	1.03	1.00	0.54	1.10
P78 20A	1.44	1.33	1.20	0.87	1.26
P78 20B	1.25	1.33	1.16	0.88	1.28
P79 21A	1.25	1.10	1.17	0.33	1.10
P79 21B	1.25	1.14	1.10	0.34	1.00
P80 22A	1.21	1.38	1.24	0.99	1.39
P80 22B	1.64	1.39	1.30	0.98	1.39
Lake Levels (1)	0.25	0.34	0.36	0.34	0.38

(1) Marine Environmental Data, Services Branch, Fisheries and Oceans, Ottawa. See Table IV for detailed data.

TABLE IV

ASH CELL GROUNDWATER QUALITY - 1984
THUNDER BAY TGS EXTENSION

RELATIVE PIEZOMETER AND LAKE WATER LEVELS - 1984
(Relative to Average Shoreline Level of 182.88 m)

Piezometer Identification	Relative Water Levels in Piezometers (m)				
	Dates Measurements Taken				
	April 19, 1984	July 6, 1984	July 26, 1984	Sept 18, 1984	Oct 26, 1984
P78 1A	1.18	1.13	1.04	1.10	1.32
P78 1B	1.28 (F)	1.26	1.16	1.15	1.33
P78 2A	1.24	1.29	1.24	1.24	1.28
P78 2B	1.39	1.40	1.34	1.31	1.37
P78 3A	1.48	1.32	1.26	1.21	1.27
P78 3B	1.50	1.32	1.27	1.20	1.28
P78 4A	1.25	1.33	1.28	1.19	1.26
P78 4B	1.33	1.27	1.19	1.18	1.24
P78 4C	1.53	1.27	1.23	1.20	1.25
P78 5A	1.31 (F)	1.32	1.22	1.09	1.14
P78 5B	1.12 (F)	1.17	1.13	1.12	1.14
P78 6A	1.28	1.14	1.13	1.04	1.08
P78 6B	1.26	1.05	1.13	1.06	1.08
P78 7A	0.90	1.08	1.01	1.06	1.08
P78 7B	1.10	1.15	1.10	1.06	1.06
P78 8A	1.09	1.12	1.05	1.04	1.07
P78 8B	1.07	1.14	1.06	1.03	1.07
P78 9A	0.87	0.90	0.91	0.89	0.90
P78 9B	1.04	0.90	0.83	0.87	0.87
P78 10A	1.19	1.08	1.08	1.03	1.04
P78 10B	0.63	1.06	1.04	1.05	1.04
P78 11A	1.08	1.09	1.06	1.04	1.04
P78 11B	1.05	1.08	1.05	1.04	1.04
P78 12A	1.02 (F)	1.05	-	-	0.99
P78 12B	1.09	1.11	-	-	1.03
P78 13A	1.05	1.08	1.04	1.04	1.04
P78 13B	1.04	1.07	1.02	1.03	1.04
P78 14A	-	-	-	-	-
P78 14B	-	-	-	-	-
P78 15A	1.07	1.08	1.06	1.04	1.08
P78 15B	1.07	1.08	1.08	1.04	1.07
P78 16A	1.13	1.13	1.09	1.10	1.16
P78 16B	1.12	1.18	1.15	1.06	1.15
P78 17A	-	-	-	-	-
P78 17B	-	-	-	-	-
P78 18A	1.27	1.24	1.16	1.01	1.19
P78 18B	1.30	1.26	1.17	1.02	1.20
P78 19A	1.32	1.25	1.17	0.75	1.09
P78 19B	1.30	1.25	1.18	0.84	1.12
P78 20A	1.47	1.34	1.29	1.19	1.26
P78 20B	0.98 (F)	1.36	1.29	1.19	1.27
P79 21A	1.22	0.27	1.11	0.66	0.96
P79 21B	1.23	0.12	1.12	0.67	1.00
P80 22A	1.57	1.41	1.38	1.29	1.32
P80 22B	1.63	1.42	1.40	1.21	1.33
Lake Water (1)	0.13	0.39	0.39	0.37	0.35

(1) Relative Average Monthly Lake Levels (relative to 182.88 m average lake level) for Station 10050, Thunder Bay Harbour. Obtained from Marine Environmental Data, Services Branch, Fisheries and Oceans, Ottawa.

APPENDIX B

TOTAL PRECIPITATION
THUNDER BAY 'A' - 1984
(Airport)

From

ENVIRONMENT CANADA
ATMOSPHERIC ENVIRONMENT SERVICE
CANADIAN CLIMATE CENTRE
DOWNSVIEW, ONTARIO

ANNUAL METEOROLOGICAL SUMMARY
SOMMAIRE MÉTÉOROLOGIQUE ANNUEL

STATION NAME / NOM DE LA STATION THUNDER BAY "A" ONTARIO YEAR/ANNÉE: 1979

METEOROLOGICAL DATA FOR THE YEAR / DONNÉES MÉTÉOROLOGIQUE POUR L'ANNÉE

TOTAL DAILY PRECIPITATION OF RAIN & SNOW / PRECIPITATION TOTALE DE PLUIE ET DE NEIGE

DATE	JAN JAN	FEB FEV	MAR MAR	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOÛT	SEPT SEP	OCT OCT	NOV NOV	DEC DEC
1		TR	TR			1.2			11.9	6.7	0.2	
2	TR	0.4	14.4		0.3				2.0	1.0	TR	
3	TR	0.2	11.6			TR		0.2	TR	8.5	TR	TR
4		TR	0.4		TR	3.2	TR	4.4		0.2	TR	6.6
5		0.8		TR					1.2			0.2
6	TR	3.9			5.4	9.4		0.2	0.2	TR	TR	0.4
7		0.6	TR		8.0				0.3		3.6	
8	0.5	TR	1.2	12.2	6.8		1.4			1.8	0.6	TR
9		TR	2.3		22.2	7.6	TR	1.8	2.0	TR	TR	3.5
10		TR	TR		34.4	10.4			1.0	TR	TR	8.0
11	TR	0.6	1.0		TR				15.4	7.0	0.8	2.0
12	TR	2.0	3.9	20.8				9.9		0.4	TR	TR
13		3.6	0.2	3.6	TR			2.4	0.4		0.8	0.5
14		7.9	1.8		TR	0.2			0.2	TR	0.2	TR
15		4.1				2.8	TR		0.4		TR	TR
16	0.4	TR				TR				0.4		
17	5.0		0.2		4.6							
18	0.2	TR	6.2		0.8		4.2			15.9		2.7
19	1.0		8.4	0.8	TR		TR		7.2	10.6	2.2	
20	5.1		TR	6.4	1.0	11.1			1.5	TR		
21	3.2	10.9	TR	TR		1.8	14.2			0.4		
22	TR	9.9	25.8	2.4	2.4			10.5		13.8	TR	TR
23	0.4	11.6	3.2	6.0			0.2	6.3	TR	2.2	4.8	TR
24	TR			1.8			8.4	0.6		TR	TR	TR
25		TR		1.4		3.1	TR	TR		TR		
26		TR		TR			0.2	0.8		TR	0.9	
27	0.4		TR	TR					3.0	7.4	TR	
28	TR	4.8	10.6			0.4		6.8	TR	TR	1.8	
29						1.2		7.2	0.4	TR	TR	
30	TR		11.7		0.4	TR	9.2		0.4		TR	
31	TR				10.2			17.0		14.8		

ANNUAL METEOROLOGICAL SUMMARY
SOMMAIRE MÉTÉOROLOGIQUE ANNUEL

for/pour THUNDER BAY "A" ONTARIO YEAR/ANNÉE: 1980

METEOROLOGICAL DATA FOR THE YEAR / DONNÉES MÉTÉOROLOGIQUE POUR L'ANNÉE

TOTAL DAILY PRECIPITATION OF RAIN & SNOW / PRECIPITATION TOTALE DE PLUIE ET NEIGE

DATE	JAN JAN	FEB FEV	MAR MAR	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOÛT	SEPT SEP	OCT OCT	NOV NOV	DEC DEC
1						6.8	2.6	0.2	5.8	0.4		TR
2	TR								0.2			
3	TR		TR						4.2		0.2	7.8
4	0.5	0.4	TR				16.1	6.2	6.2			TR
5	1.4	0.4			TR	TR			TR		TR	2.0
6	24.5	TR		2.4	0.8	TR	0.6		0.8			0.6
7	1.2			1.8	TR	5.0	2.6		0.2			1.8
8	TR	TR		2.0	0.4	0.7		1.8	30.6		19.4	0.4
9	TR	TR	0.2	11.3				TR			0.6	1.0
10	6.4	1.0	2.2	TR	11.4		TR	0.2		6.8	TR	
11	12.1	0.3		TR	TR			3.0		0.4		TR
12	2.3	TR	8.2	TR	0.2	3.1	TR	2.6	29.8		7.8	8.6
13	0.4	TR	7.4	TR				22.3	44.7		0.4	TR
14		TR			TR	3.8	10.8	TR		TR	TR	
15	6.8	TR	TR	TR					TR		TR	0.8
16			8.9				40.5		TR	7.6	TR	1.8
17	TR		0.2	TR		TR		5.5	3.8	5.2	TR	7.0
18	TR		TR				2.2	TR	6.0			TR
19	TR	4.2	TR	0.2				1.9	33.9	TR		
20		TR	3.5				1.2	3.0		1.2	5.6	
21		TR				TR	38.8	0.8		TR		TR
22	TR	1.4					1.9		0.7	TR		2.3
23		1.0	1.8	TR		8.2		0.6		13.1	0.2	TR
24	0.4	0.4		1.9			0.6	15.0	4.4	28.6	TR	
25	TR			0.7						0.2		1.2
26	TR	2.8		0.2	9.6				0.8	TR		TR
27	1.2		4.5		TR	0.8	2.2	1.8		TR	0.6	0.8
28	TR					25.9	7.4	TR			5.5	TR
29	TR					4.4		34.8	1.8		0.4	TR
30					10.4	TR	0.2	24.3	1.0		TR	10.0
31										TR		1.4

· TR = Less than 0.2 mm

ANNUAL METEOROLOGICAL SUMMARY
SOMMAIRE MÉTÉOROLOGIQUE ANNUEL

for/pour THUNDER BAY "A", ONTARIO

YEAR/ANNÉE: 1981

METEOROLOGICAL DATA FOR THE YEAR / DONNÉES MÉTÉOROLOGIQUE POUR L'ANNÉE

TOTAL DAILY PRECIPITATION OF RAIN & SNOW / PRECIPITATION TOTALE DE PLUIE ET DE NEIGE

DATE	JAN JAN	FEB FEV	MAR MAR	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOÛT	SEPT SEP	OCT OCT	NOV NOV	DEC DEC
1	TR	5.2	1.0	0.4		23.5		TR	0.3	21.1		1.1
2			TR	TR	15.8	16.3						0.2
3		TR	5.2	13.0	2.4	31.0	3.2	0.4				3.7
4			TR	5.0	1.0		TR	0.2		3.1		0.8
5	1.5	0.4	0.8		0.8	1.9				7.8	TR	TR
6	0.4	TR						3.6		1.2		TR
7		1.3	TR			10.6		10.3	13.6			TR
8	TR	TR			TR	0.8	0.3	1.9		0.5		TR
9	TR	TR	0.2		5.4	2.4		5.8			TR	TR
10		0.4	0.8	2.2		1.6		TR		1.6	0.6	
11	TR		TR			2.8			0.4	TR	TR	
12	TR		TR			0.9						0.8
13	0.2	1.2		10.7		8.5			0.4	16.4		TR
14	1.3	TR		TR		4.8		3.5		1.5		0.2
15	TR	0.4			TR				TR		0.2	TR
16	TR	1.4	TR	0.6			TR		TR		1.8	TR
17		3.8	TR	TR		4.6	3.2		TR	8.6		TR
18		3.1	TR			3.8	TR			0.6		TR
19			0.2	TR			TR			1.4	TR	
20	TR		TR			9.6	0.3			0.6	0.6	3.0
21		TR	TR	0.6		TR				TR	TR	1.8
22		30.5	TR	2.4	TR			TR		3.2		1.6
23		1.9		13.3	2.3	TR			0.2	TR		0.6
24		TR			23.3	23.6	0.4		1.3	2.2	0.3	
25		TR	TR		3.1		TR		0.2	0.6	5.0	0.2
26	1.2	TR	TR	0.6					9.4		14.1	4.0
27	TR	5.7		0.2					1.1		1.0	7.4
28	0.8	0.2	12.8		0.6	16.3	TR			TR	TR	
29	TR		1.8	0.4	4.8	7.2		2.0		1.0	TR	TR
30			1.6		TR				11.2			2.8
31	2.4		8.7				TR	57.9				2.0

NOTE: TR = less than 0.2 mm

ANNUAL METEOROLOGICAL SUMMARY
SOMMAIRE MÉTÉOROLOGIQUE ANNUEL

for/pour THUNDER BAY "A", ONTARIO YEAR/ANNÉE: 1982

METEOROLOGICAL DATA FOR THE YEAR / DONNÉES MÉTÉOROLOGIQUE POUR L'ANNÉE

TOTAL DAILY PRECIPITATION OF RAIN & SNOW / PRECIPITATION TOTALE DE PLUIE ET DE NEIGE

DATE	JAN JAN	FEB FEV	MAR MAR	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOÛT	SEPT SEP	OCT OCT	NOV NOV	DEC DEC
1		1.8	0.2	TR		1.0			4.0	TR		TR
2	25.0	0.2		14.1			0.4	3.8	4.1	8.6		2.2
3	1.2			12.0			16.8	28.0			8.9	0.4
4			TR	0.2	3.5				0.2	0.3	4.5	
5	4.4	TR			6.2		34.6	TR			TR	0.2
6		0.2	TR		5.5		44.5	1.2		36.1	TR	TR
7		TR				TR	29.2	3.6	0.2	20.8		
8	0.9		0.2				TR	3.4		TR	TR	TR
9	0.2		0.2		4.2	21.0	0.4	0.2		18.0		TR
10	0.9		9.6	0.4	16.8	1.0	4.2		1.8	21.0	12.1	TR
11	TR	TR	TR		1.2	1.2	2.2		TR	3.6	0.4	
12			17.7	3.4	0.6	TR	6.6		13.2	12.1	2.5	TR
13	TR	0.2	TR		19.6	4.8	19.6		0.8	TR	TR	0.2
14	1.3	1.2			2.0	14.8	1.0			TR		3.2
15	0.2			5.3	TR	TR	0.2			TR		TR
16	0.2		1.3	6.3	3.2	6.9	0.9		1.0			TR
17			TR	0.3	3.4	0.8	27.2		7.6	3.3		2.4
18	TR	TR	5.2		4.3			52.4	0.2	8.2		TR
19	6.6				TR	TR			2.8	0.7	1.8	0.2
20		TR	0.4			1.8				2.1	20.0	0.2
21	0.3		1.0			8.0	3.2	7.6			TR	3.0
22	7.2	3.2						6.6			2.2	0.4
23	7.9							1.0	7.6		TR	7.5
24			4.4			4.9		3.2	0.6		TR	
25			0.3					2.0				1.9
26	TR	TR					0.2			TR		
27	TR					7.1	0.8		1.4	TR		1.8
28	TR	4.6							1.8	3.1		19.4
29	1.8		0.4		3.8		8.3	4.3	2.8	3.5		TR
30	TR		22.9							0.2	TR	TR
31			1.0		2.8			9.0				0.2

NOTE: TR = less than 0.2 mm

ANNUAL METEOROLOGICAL SUMMARY
SOMMAIRE MÉTÉOROLOGIQUE ANNUEL

for/pour THUNDER BAY "A", ONTARIO YEAR/ANNÉE: 1983

METEOROLOGICAL DATA FOR THE YEAR / DONNÉES MÉTÉOROLOGIQUE POUR L'ANNÉE

TOTAL DAILY PRECIPITATION OF RAIN & SNOW / PRECIPITATION TOTALE DE PLUIE ET DE NEIGE

DATE	JAN JAN	FEB FEV	MAR MAR	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOÛT	SEPT SEP	OCT OCT	NOV NOV	DEC DEC
1	1.4		TR	2.8						2.2		TR
2		TR	0.4			TR	5.4	15.6		7.2	TR	TR
3	0.2		4.0		TR	8.6	26.8	4.6	0.2	2.4		0.2
4	0.8		0.6		TR	18.1	6.6		2.6	0.2		
5	TR	0.8	1.2			0.8			4.6	2.3		TR
6	3.2		16.4	TR		0.4				0.2		
7	TR		13.6	TR			0.2	14.8		6.3		
8			TR			5.2			0.7	TR		TR
9	4.1	1.6	1.9						7.7		2.5	
10	3.2	2.4		7.3		0.2		38.9	20.5	3.6		1.9
11		2.0								13.7	TR	19.4
12	1.4	TR			TR	TR				7.4		TR
13	2.6		0.2	16.7	0.4			TR	4.3	10.9	2.0	5.5
14	4.6	TR	TR	23.0	TR	1.3				7.8	0.5	TR
15		TR		1.0		3.6			1.6	7.8	TR	1.0
16	2.0	TR	TR	0.2		0.4	5.6		5.4	1.0	TR	0.2
17	TR	0.2	1.6		TR				0.3	0.2	TR	TR
18		4.5	0.2		TR		0.4	TR	TR		TR	TR
19	0.2	9.8			0.9			12.6			10.0	
20		6.9			4.4				0.6		33.9	
21	TR	TR						12.3	0.2		4.2	7.7
22					11.2	2.1			0.4		3.3	1.0
23	TR	TR					0.4				37.5	TR
24	TR				3.4	10.1		0.8		1.0	TR	TR
25	TR											0.8
26				5.0		7.2		0.2		TR	TR	TR
27	TR	5.4	TR				13.4	TR	0.4		TR	
28	TR	0.6		3.4	10.6		0.8	TR	1.4	0.5	7.2	TR
29	12.8				11.1			8.2	17.1		2.6	TR
30	0.4		1.4		5.9	9.9	TR		15.8		TR	
31	0.2		0.6				2.8					

ANNUAL METEOROLOGICAL SUMMARY
SOMMAIRE MÉTÉOROLOGIQUE ANNUEL

for/pour THUNDER BAY "A", ONTARIO YEAR/ANNÉE: 1984

METEOROLOGICAL DATA FOR THE YEAR / DONNÉES MÉTÉOROLOGIQUE POUR L'ANNÉE

TOTAL DAILY PRECIPITATION OF RAIN & SNOW / PRÉCIPITATION TOTALE DE PLUIE ET DE NEIGE

DATE	JAN JAN	FEB FEV	MAR MAR	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOÛT	SEPT SEP	OCT OCT	NOV NOV	DEC DEC
1	0.2	0.3			TR	8.2			1.0		TR	TR
2		5.6				1.6	4.4		1.2	0.8	TR	2.8
3	0.6	0.8					1.0		0.4		1.2	TR
4	0.2	1.6	0.2			0.4	1.4		1.0	2.6	11.4	TR
5	2.7	0.2	2.6		0.4	11.6	7.8				TR	2.4
6	TR	TR	TR			9.4	1.0	10.2				TR
7	3.5	TR			19.6	2.6		12.6	0.2		TR	TR
8					1.9	7.4	TR	25.8	13.7		3.2	
9	TR					0.8	TR	3.2	3.2			
10			0.2		0.4	26.1			0.2	TR	TR	
11			0.2		0.4	TR	9.6	TR	2.5			
12	0.5	10.4	0.2			8.4	1.1		6.4	TR		
13	2.2	12.3	2.2	TR		6.4	6.6		TR			TR
14	TR	TR	0.8	TR			0.4	TR	1.4		3.4	TR
15	TR		5.2	TR		1.4	1.0	5.3		11.4	0.9	10.3
16	0.3		TR		TR		4.4	TR		2.6	TR	30.8
17		1.2	0.2			0.2	10.2	2.6		16.6		2.6
18						TR						0.6
19	0.2				6.4					28.8	TR	0.2
20			2.7		TR			TR	TR	TR		0.4
21	TR	TR	0.9		12.2			12.2	0.2	0.2		6.5
22	3.6		TR		5.2	0.4	32.9	TR	1.0	TR	0.4	TR
23	TR	TR			TR				0.2			
24	0.2	TR			4.2	TR			8.2	TR		
25		TR		0.6		5.8	7.2	1.2	5.1	2.0		TR
26	1.1			5.8	TR	27.6	0.6		0.6		0.2	5.8
27	2.2	TR		16.4		2.4		13.2		6.4	10.8	0.8
28	3.2			0.6						TR	0.6	6.8
29	TR			0.6	TR			0.2			TR	0.6
30	0.2			2.5	0.6		1.4			3.8	TR	0.4
31	TR				0.4		6.0			7.4		

NOTE: TR = less than 0.2 mm

APPENDIX C

GROUNDWATER CHEMICAL ANALYSIS - TBTGS - 1984

(All values are in mg/L except pH and conductivity

- pH in pH units
- conductivity in mS/m

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 01A

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	--	--	<5.0	--
ALKHCO3	--	--	510.	--
ALKOH	--	--	<5.0	--
ALKTOT	--	--	510.	580.
B	--	--	.13	--
CA	--	--	160.	--
CL	--	--	44.	--
COND	--	--	110.	140.
K	--	--	1.8	--
MG	--	--	55.	--
NA	--	--	17.	--
NO3	--	--	<.20	--
PH	--	--	6.6	6.3
SO4	--	--	79.	--
SR	--	--	.28	--

C2

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 01B

TEST	840419	840420 *	840726	840727 *
		SAMPLING DATE		
ALKCO3	--	--	<5.0	--
ALKHCO3	--	--	490.	--
ALKOH	--	--	<5.0	--
ALKTOT	--	--	490.	500.
B	--	--	.43	--
CA	--	--	160.	--
CL	--	--	81.	--
COND	--	--	110.	140.
K	--	--	2.9	--
MG	--	--	50.	--
NA	--	--	12.	--
NO3	--	--	<.20	--
PH	--	--	6.8	6.4
SO4	--	--	29.	--
SR	--	--	.43	--

C3

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 02A

TEST	SAMPLING DATE 840419	840420*	840726	840727*
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	430.	--	450.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	430.	440.	450.	480.
B	.12	--	.13	--
CA	100.	--	110.	--
CL	4.0	--	5.6	--
COND	88.	180.	81.	85.
K	1.0	--	1.3	--
MG	48.	--	45.	--
NA	13.	--	12.	--
NO3	<.20	--	<.20	--
PH	7.2	6.4	6.7	6.3
SO4	36.	--	20.	--
SR	.15	--	.18	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 02B

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	520.	--	480.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	520.	530.	480.	610.
B	.27	--	.21	--
CA	160.	--	130.	--
CL	25.	--	7.7	--
COND	92.	120.	85.	99.
K	1.2	--	1.3	--
MG	46.	--	42.	--
NA	6.6	--	7.9	--
NO3	<.20	--	<.20	--
PH	7.2	6.4	6.9	6.4
SO4	29.	--	17.	--
SR	.29	--	.23	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 03A

TEST	840419	840420*	840726	840727*
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	460.	--	500.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	460.	640.	500.	520.
B	.14	--	.12	--
CA	120.	--	120.	--
CL	9.5	--	11.	--
COND	94.	84.	87.	110.
K	1.2	--	1.5	--
MG	41.	--	43.	--
NA	16.	--	20.	--
NO3	<.20	--	<.20	--
PH	7.7	6.6	7.0	6.5
SO4	15.	--	1.0	--
SR	.23	--	.28	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 03B

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	380.	--	590.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	380.	390.	590.	650.
B	.25	--	.20	--
CA	87.	--	150.	--
CL	39.	--	16.	--
COND	86.	110.	100.	120.
K	1.2	--	.93	--
MG	29.	--	53.	--
NA	22.	--	10.	--
NO3	<.20	--	<.20	--
PH	7.8	6.7	6.9	6.6
SO4	95.	--	1.1	--
SR	.25	--	.25	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 04A

TEST	840419	840420*	840726	840727*
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	350.	--	340.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	350.	360.	340.	430.
B	<.030	--	.10	--
CA	87.	--	78.	--
CL	12.	--	10.	--
COND	74.	71.	63.	70.
K	1.1	--	1.0	--
MG	28.	--	27.	--
NA	21.	--	15.	--
NO3	<.20	--	<.20	--
PH	7.3	6.6	6.8	6.6
SO4	3.4	--	.30	--
SR	.19	--	.17	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 04B

TEST	840419	840420*	840726	840727*
			SAMPLING DATE	
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	480.	--	430.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	480.	490.	430.	540.
B	.070	--	.17	--
CA	130.	--	110.	--
CL	22.	--	17.	--
COND	97.	88.	79.	91.
K	1.2	--	1.6	--
MG	40.	--	34.	--
NA	26.	--	32.	--
NO3	<.20	--	<.20	--
PH	7.2	6.4	7.0	6.5
SO4	48.	--	.90	--
SR	.34	--	.36	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 04C

TEST	840419	840420*	840726	840727*
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	590.	--	460.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	590.	210.	460.	530.
B	.13	--	.12	--
CA	140.	--	110.	--
CL	9.0	--	9.5	--
COND	81.	92.	81.	110.
K	1.2	--	1.2	--
MG	50.	--	40.	--
NA	17.	--	14.	--
NO3	<.20	--	<.20	--
PH	6.8	6.5	6.7	6.4
SO4	6.8	--	5.5	--
SR	.29	--	.24	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 05A

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	--	--	<5.0	--
ALKHCO3	--	--	370.	--
ALKOH	--	--	<5.0	--
ALKTOT	--	--	370.	460.
B	--	--	.060	--
CA	--	--	100.	--
CL	--	--	18.	--
COND	--	--	73.	91.
K	--	--	1.2	--
MG	--	--	35.	--
NA	--	--	15.	--
NO3	--	--	<.20	--
PH	--	--	6.6	6.3
SO4	--	--	22.	--
SR	--	--	.19	--

C11

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 05B

TEST	840419	840420 *	840726	840727 *
			SAMPLING DATE	
ALKCO3	--	--	<5.0	--
ALKHCO3	--	--	220.	--
ALKOH	--	--	<5.0	--
ALKTOT	--	--	220.	370.
B	--	--	.080	--
CA	--	--	74.	--
CL	--	--	10.	--
COND	--	--	68.	80.
K	--	--	.33	--
MG	--	--	35.	--
NA	--	--	8.6	--
NO3	--	--	<.20	--
PH	--	--	6.4	6.3
SO4	--	--	130.	--
SR	--	--	.11	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 06A

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	720.	--	600.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	720.	720.	600.	690.
B	.13	--	.11	--
CA	160.	--	150.	--
CL	16.	--	15.	--
COND	120.	110.	100.	120.
K	1.1	--	1.4	--
MG	63.	--	52.	--
NA	28.	--	24.	--
NO3	<.20	--	<.20	--
PH	6.8	6.5	6.7	6.5
SO4	.40	--	2.2	--
SR	.38	--	.32	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 06B

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	64.	--	<5.0	--
ALKHCO3	570.	--	720.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	630.	720.	720.	810.
B	.11	--	.13	--
CA	150.	--	170.	--
CL	13.	--	1.4	--
COND	120.	140.	120.	150.
K	.39	--	.33	--
MG	71.	--	73.	--
NA	18.	--	20.	--
NO3	<.20	--	<.20	--
PH	8.1	6.4	6.7	6.4
SO4	.90	--	.40	--
SR	.23	--	.25	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 07A

TEST	840419	840420*	840726	840727*
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	400.	--	330.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	400.	410.	330.	400.
B	.070	--	.090	--
CA	95.	--	79.	--
CL	16.	--	12.	--
COND	74.	94.	63.	84.
K	.80	--	.63	--
MG	35.	--	29.	--
NA	17.	--	14.	--
NO3	<.20	--	<.20	--
PH	6.9	6.4	6.6	6.2
SO4	.60	--	.20	--
SR	.20	--	.16	--

C15

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*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 07B

TEST	840419	840420*	840726	840727*
	SAMPLING DATE			
ALKCO3	34.	--	<5.0	--
ALKHCO3	290.	--	320.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	330.	350.	320.	340.
B	.080	--	.090	--
CA	72.	--	73.	--
CL	10.	--	10.	--
COND	61.	77.	59.	84.
K	.48	--	.42	--
MG	32.	--	32.	--
NA	15.	--	12.	--
NO3	<.20	--	<.20	--
PH	8.1	6.4	6.5	6.2
SO4	.30	--	.50	--
SR	.13	--	.12	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 08A

TEST	SAMPLING DATE 840419	840420 *	840726	840727 *
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	380.	--	390.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	380.	460.	390.	510.
B	.080	--	.090	--
CA	72.	--	90.	--
CL	8.0	--	7.2	--
COND	68.	100.	71.	99.
K	.91	--	.92	--
MG	38.	--	38.	--
NA	9.6	--	10.	--
NO3	<.20	--	<.20	--
PH	6.5	6.5	6.5	6.4
SO4	.30	--	<.20	--
SR	.14	--	.17	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 08B

TEST	SAMPLING DATE 840419	840420 *	840726	840727 *
ALKCO3	37.	--	<5.0	--
ALKHCO3	420.	--	480.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	450.	460.	480.	610.
B	.18	--	.20	--
CA	96.	--	100.	--
CL	9.2	--	8.0	--
COND	77.	100.	82.	120.
K	.70	--	1.0	--
MG	53.	--	51.	--
NA	11.	--	16.	--
NO3	<.20	--	<.20	--
PH	8.0	6.5	6.7	6.4
SO4	.50	--	1.2	--
SR	.13	--	.16	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 09A

TEST	840419	840420 *	840726	840727 *
			SAMPLING DATE	
ALKCO3	--	--	<5.0	--
ALKHCO3	--	--	260.	--
ALKOH	--	--	<5.0	--
ALKTOT	--	--	260.	330.
B	--	--	.090	--
CA	--	--	62.	--
CL	--	--	14.	--
COND	--	--	52.	66.
K	--	--	.87	--
MG	--	--	27.	--
NA	--	--	10.	--
NO3	--	--	<.20	--
PH	--	--	6.6	6.2
SO4	--	--	1.9	--
SR	--	--	.14	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 09B

TEST	840419	840420 *	840726	840727 *
			SAMPLING DATE	
ALKCO3	--	--	<5.0	--
ALKHCO3	--	--	240.	--
ALKOH	--	--	<5.0	--
ALKTOT	--	--	240.	330.
B	--	--	.080	--
CA	--	--	55.	--
CL	--	--	13.	--
COND	--	--	47.	60.
K	--	--	1.0	--
MG	--	--	22.	--
NA	--	--	9.5	--
NO3	--	--	<.20	--
PH	--	--	6.6	6.4
SO4	--	--	.70	--
SR	--	--	.090	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 10A

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	410.	--	390.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	410.	420.	390.	450.
B	.10	--	.10	--
CA	87.	--	86.	--
CL	15.	--	10.	--
COND	75.	82.	70.	75.
K	.77	--	.96	--
MG	46.	--	41.	--
NA	14.	--	15.	--
NO3	<.20	--	<.20	--
PH	7.3	6.4	6.8	6.5
SO4	.90	--	3.4	--
SR	.19	--	.19	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 10B

TEST	840419	840420 *	840726	840727 *
		SAMPLING DATE		
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	450.	--	430.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	450.	460.	430.	450.
B	.10	--	.090	--
CA	90.	--	96.	--
CL	12.	--	7.8	--
COND	80.	83.	79.	98.
K	.85	--	.45	--
MG	51.	--	52.	--
NA	16.	--	15.	--
NO3	<.20	--	<.20	--
PH	6.9	6.5	6.9	6.4
SO4	3.0	--	29.	--
SR	.19	--	.16	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 11A

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	630.	--	470.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	630.	520.	470.	570.
B	.21	--	.14	--
CA	140.	--	110.	--
CL	17.	--	15.	--
COND	110.	100.	84.	96.
K	1.1	--	.81	--
MG	69.	--	50.	--
NA	24.	--	17.	--
NO3	<.20	--	<.20	--
PH	7.0	6.4	6.7	6.4
SO4	.60	--	5.1	--
SR	.37	--	.27	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 11B

TEST	SAMPLING DATE 840419	840420*	840726	840727 *
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	590.	--	560.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	590.	630.	560.	650.
B	.13	--	.12	--
CA	130.	--	130.	--
CL	19.	--	14.	--
COND	100.	110.	98.	95.
K	.68	--	.32	--
MG	72.	--	64.	--
NA	15.	--	14.	--
NO3	<.20	--	<.20	--
PH	6.9	6.4	6.7	6.4
SO4	2.4	--	13.	--
SR	.29	--	.24	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 13A

TEST	SAMPLING DATE 840419	840420*	840726	840727 *
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	290.	--	270.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	290.	310.	270.	340.
B	.14	--	.14	--
CA	75.	--	66.	--
CL	19.	--	13.	--
COND	60.	73.	54.	83.
K	.99	--	1.1	--
MG	34.	--	29.	--
NA	13.	--	9.1	--
NO3	<.20	--	<.20	--
PH	7.2	6.2	6.6	6.3
SO4	18.	--	11.	--
SR	.15	--	.14	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 13B

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	270.	--	280.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	270.	300.	280.	370.
B	.20	--	.18	--
CA	76.	--	65.	--
CL	16.	--	13.	--
COND	56.	76.	54.	71.
K	1.1	--	.77	--
MG	30.	--	32.	--
NA	12.	--	10.	--
NO3	<.20	--	<.20	--
PH	7.2	6.1	6.9	6.1
SO4	6.5	--	4.3	--
SR	.090	--	.090	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 15A

TEST	840419	840420*	840726	840727 *
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	330.	--	320.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	330.	350.	320.	380.
B	.090	--	.070	--
CA	86.	--	86.	--
CL	15.	--	16.	--
COND	68.	90.	65.	87.
K	1.6	--	2.1	--
MG	37.	--	33.	--
NA	11.	--	12.	--
NO3	<.20	--	<.20	--
PH	6.5	6.3	6.6	6.4
SO4	34.	--	25.	--
SR	.20	--	.26	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 15B

TEST	SAMPLING DATE 840419	840420 *	840726	840727 *
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	320.	--	410.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	320.	330.	410.	500.
B	.14	--	.18	--
CA	87.	--	120.	--
CL	16.	--	21.	--
COND	65.	80.	87.	97.
K	1.6	--	2.4	--
MG	34.	--	52.	--
NA	7.9	--	10.	--
NO3	<.20	--	<.20	--
PH	6.7	6.3	6.6	6.1
SO4	19.	--	70.	--
SR	.16	--	.16	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 16A

TEST	840419	840420*	840726	840727 *
			SAMPLING DATE	
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	140.	--	290.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	140.	310.	290.	420.
B	1.8	--	2.4	--
CA	90.	--	90.	--
CL	12.	--	13.	--
COND	56.	98.	78.	110.
K	1.3	--	1.6	--
MG	36.	--	32.	--
NA	32.	--	35.	--
NO3	<.20	--	<.20	--
PH	6.5	6.2	6.4	6.1
SO4	230.	--	120.	--
SR	.21	--	.19	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 16B

TEST	840419	840420 *	840726	840727 *
			SAMPLING DATE	
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	240.	--	300.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	240.	250.	300.	350.
B	.73	--	.61	--
CA	72.	--	120.	--
CL	10.	--	10.	--
COND	62.	72.	78.	100.
K	3.8	--	2.4	--
MG	16.	--	22.	--
NA	40.	--	15.	--
NO3	<.20	--	<.20	--
PH	7.8	6.3	6.8	6.1
SO4	87.	--	130.	--
SR	.24	--	.19	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 18A

TEST	840419	840420 *	840726	840727 *
			SAMPLING DATE	
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	390.	--	340.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	390.	390.	340.	380.
B	.35	--	.42	--
CA	140.	--	110.	--
CL	49.	--	27.	--
COND	95.	100.	73.	86.
K	1.2	--	.87	--
MG	38.	--	25.	--
NA	17.	--	12.	--
NO3	<.20	--	<.20	--
PH	7.3	6.4	7.1	6.3
SO4	80.	--	32.	--
SR	.51	--	.39	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 18B

TEST	840419	840420 *	840726	840727 *
		SAMPLING DATE		
ALKCO3	39.	--	<5.0	--
ALKHCO3	300.	--	380.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	330.	300.	380.	400.
B	.33	--	.30	--
CA	120.	--	110.	--
CL	28.	--	16.	--
COND	74.	63.	73.	83.
K	1.2	--	1.3	--
MG	30.	--	32.	--
NA	14.	--	9.6	--
NO3	<.20	--	<.20	--
PH	8.3	6.8	7.5	6.4
SO4	54.	--	22.	--
SR	.32	--	.18	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 19A

TEST	840419	840420 *	840726	840727 *
		SAMPLING DATE		
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	170.	--	150.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	170.	190.	150.	220.
B	.080	--	.12	--
CA	62.	--	50.	--
CL	29.	--	10.	--
COND	46.	50.	33.	80.
K	.99	--	.83	--
MG	15.	--	14.	--
NA	8.3	--	7.3	--
NO3	<.20	--	<.20	--
PH	7.5	6.6	7.1	7.0
SO4	17.	--	12.	--
SR	.10	--	.080	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 19B

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	--	--	<5.0	--
ALKHCO3	--	--	96.	--
ALKOH	--	--	<5.0	--
ALKTOT	--	--	96.	180.
B	--	--	.090	--
CA	--	--	29.	--
CL	--	--	6.8	--
COND	--	29.	23.	--
K	--	--	.51	--
MG	--	--	12.	--
NA	--	--	5.8	--
NO3	--	--	<.20	--
PH	--	6.3	7.1	6.7
SO4	--	--	17.	--
SR	--	--	.060	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 20A

TEST	840419	840420 *	840726	840727 *
		SAMPLING DATE		
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	250.	--	460.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	250.	280.	460.	480.
B	.64	--	1.0	--
CA	87.	--	170.	--
CL	14.	--	14.	--
COND	68.	72.	110.	140.
K	1.2	--	2.1	--
MG	25.	--	64.	--
NA	32.	--	19.	--
NO3	<.20	--	<.20	--
PH	7.6	6.5	6.6	6.2
SO4	94.	--	230.	--
SR	.15	--	.20	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 20B

TEST	SAMPLING DATE 840419	840420*	840726	840727*
ALKCO3	30.	--	<5.0	--
ALKHCO3	150.	--	460.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	180.	210.	460.	490.
B	.24	--	.50	--
CA	570.	--	180.	--
CL	6.7	--	15.	--
COND	45.	49.	110.	140.
K	1.1	--	2.2	--
MG	19.	--	66.	--
NA	14.	--	17.	--
NO3	<.20	--	<.20	--
PH	8.3	6.6	6.7	6.1
SO4	52.	--	230.	--
SR	.080	--	.24	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 21A

TEST	840419	840420*	840726	840727*
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	180.	--	180.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	180.	200.	180.	180.
B	.11	--	.11	--
CA	51.	--	46.	--
CL	15.	--	14.	--
COND	42.	43.	41.	46.
K	1.1	--	1.1	--
MG	20.	--	15.	--
NA	8.0	--	7.3	--
NO3	<.20	--	<.20	--
PH	7.7	6.5	7.1	6.3
SO4	17.	--	19.	--
SR	.080	--	.070	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 21B

TEST	840419	840420*	840726	840727*
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	87.	--	110.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	87.	100.	110.	130.
B	.11	--	.40	--
CA	31.	--	37.	--
CL	16.	--	13.	--
COND	29.	30.	29.	35.
K	1.2	--	1.5	--
MG	11.	--	11.	--
NA	10.	--	8.9	--
NO3	<.20	--	<.20	--
PH	7.0	5.9	6.7	6.3
SO4	32.	--	17.	--
SR	.060	--	.070	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 22A

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	320.	--	510.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	320.	520.	510.	610.
B	.12	--	.36	--
CA	130.	--	120.	--
CL	14.	--	2.0	--
COND	63.	110.	86.	97.
K	1.3	--	.74	--
MG	49.	--	54.	--
NA	32.	--	24.	--
NO3	<.20	--	<.20	--
PH	7.5	6.7	6.9	6.3
SO4	20.	--	16.	--
SR	.26	--	.15	--

*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

ASH CELL GROUNDWATER QUALITY - TBTGS - 1984

LOCATION : 22B

TEST	840419	840420 *	840726	840727 *
	SAMPLING DATE			
ALKCO3	<5.0	--	<5.0	--
ALKHCO3	530.	--	530.	--
ALKOH	<5.0	--	<5.0	--
ALKTOT	530.	550.	530.	600.
B	.34	--	.18	--
CA	120.	--	130.	--
CL	4.0	--	20.	--
COND	92.	91.	97.	100.
K	.97	--	1.6	--
MG	59.	--	46.	--
NA	36.	--	34.	--
NO3	<.20	--	<.20	--
PH	6.9	6.3	7.0	6.8
SO4	17.	--	20.	--
SR	.19	--	.25	--

C40

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*TBTGS field data: Dated one day after actual sampling for convenience of computer retrieval.

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APPENDIX D

"Groundwater Data Analysis: Sources of Variation" by S.A. BARTLETT, RESEARCH DIVISION REPORT N85-1-K, MAY 8, 1985

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ontario hydro
research division

To: Mr. J.G. Cassan
Manager
Operations Research Dept

GROUNDWATER DATA ANALYSIS: SOURCES OF VARIATION

S. A. Bartlett

1. INTRODUCTION

A fly ash disposal site is located next to the Thunder Bay TGS (TBTGS) on Mission Island at Thunder Bay. It is considered undesirable if leachate from the ash affects the quality of the groundwater. Magnitudes of concentration levels of chemical species present in the groundwater provide measures of this quality.

The groundwater surrounding the site was monitored for possible leachate formation from the ash. For the purposes of this report, leachate is defined as present if ionic concentration levels are out of normal bounds. The first step towards defining what is normal is to study the factors that significantly influence ionic concentration levels. As explained later in this report, factors include date of sampling, location of measurement, geological stratum, and the laboratory where testing was carried out. Thus, the objective of this report is to analyze the data for sources of variation.

2. THE DATA

There are 22 permanent locations along the perimeter of the site, each having one peizometer (an observation well from which water samples are taken) per geological stratum. All locations have 2 strata except location number 4, which has 3. Water samples from each location and each stratum were extracted on each sampling occasion for a total of 45 samples. Each of these samples had tests done for up to 42 chemical species. There were several samplings per year from 1976 to 1984.

Chemical analyses of the samples was done in three different laboratories. Before 1979 analyses were performed by London Monenco Consultants Ltd (LMC). From 1979 to 1984, analyses

job	file	date	report no.
740631-531-861	809.710	May 8, 1985	N85-1-K

were either done in the field at the TBTGS or at the Research Division laboratory. All samples were taken from a different set of peizometers during the later stage and the Research Division laboratory carried out tests for more species than the laboratory at the TBTGS. No laboratory performed analysis on the same day. Table I lists the dates on which each testing location performed analysis.

The instrument for measuring concentration level was calibrated for each test on each date samples were analysed. Concentrations below a certain level were impossible to detect and will be referred to as being below detection limit. Detection limits depend on the calibration and thus may change from day to day. Summary statistics for concentration levels excluding data below detection limit are given in Table II. The number of observations below detection limit for each test are also given in the table.

3. ANALYSIS AND RESULTS

Many of the tests had a high number of concentration levels below detection limit (see Table II). Inclusion of detection limit values in the analysis introduced an additional source of variation that biased the results. Data points below detection limit were thus ignored in the statistical analysis presented in this report since they would only confuse the conclusions. As a result, 42% of the observations were rejected overall. For some species, almost all the data were rejected while, for others, none were rejected. However, these points could be taken into consideration in a future analysis.

Each chemical species was treated separately. Analysis of variance was used to investigate those factors which may influence ionic concentration levels. They are peizometer location, strata, testing site, and date. The interaction between strata and peizometer site was also included, though other interactions were ignored because they seemed to have minimum impact. Computing was done using the General Linear Models (GLM) procedure of the computer software package, Statistical Analysis System (SAS).

When analysis of variance is done using GLM, certain criteria must be met to ensure validity of the conclusions. Observations must be independent, concentration levels must be normally distributed, and all observations must have equal variances. Clearly, independence may be assumed. To check the assumption that the other two criteria are met, scatter plots of residuals of the analyses as well as normal score plots were useful. If the assumptions can be made, the residual plots should exhibit randomness while the normal score plots should be linear.

Scatter plots of the residuals from the statistical analyses showed that in all cases except pH, the residuals tended to increase as concentration level increased. Figure 1 shows examples of two benchmark species, boron (B) and strontium (Sr), as well as pH. The normal score plots exhibit non-linearity in all cases (see Figure 2). Thus, the normality and equality of variance criteria were not satisfied.

The usual procedure for correcting invalidations of assumptions is to apply a transformation to the data. The fact that scatter increased with concentration level indicated that the natural log (usually denoted by ln) transformation was a potential candidate for normalizing errors and stabilizing variance. The analyses were therefore repeated using the transformed data. The normal score plots appeared more linear (see Figure 3) while the residual plots appeared more random (see Figure 4). However, a test for normality indicated rejection of the hypothesis that the errors are normally distributed. This was probably a result of outliers. However, the transformation of the data was accepted though the outliers were not excluded at this point of the study.

The results of the analyses of variance for each test using the lognormal transformation are given in Table III. In 87% of the tests peizometer location was significant while in 42% of the tests stratum was significant. An interaction between stratum and peizometer location was significant in 68% of the cases. In those cases which have significant interaction, nonsignificant site and strata conclusions must be considered with caution. Type of laboratory was significant in 96% of the cases while date was significant in 90% of the data.

The residual plots from the transformed data indicated that there were two distinct groups of data typified by the benchmark species, boron and strontium (see Figure 4). By comparing predicted values against the other factors, in most cases the split occurred between testing done before and after January 1979. This was not surprising since testing before January 1979 was done by a different group. Table IV displays means, standard deviations and number of observations within each testing site for each species. The analyses were again performed excluding dates before January 1979. Conclusions did not change dramatically. Other dates appeared to be split from the others. However, these dates were not excluded at this time.

Peizometer location and stratum variation were expected due to geological characteristics of the disposal site. What is of greater interest is how concentration levels change over time. Thus, special consideration was given to the date of the observations.

Seasonal and yearly variation were considered as factors. Unfortunately, the data were not collected at equally spaced time intervals, precluding a time series analysis. Concentration levels for each test averaged over strata and peizometer locations were plotted for each month/year combination. Sample plots are shown in Figure 5 for the species B, Sr, and pH. To analyse the year and month factors, it was assumed that months would have a linear trend for each year. The hypotheses of interest were (i) there was no overall increase or decrease in concentration levels over month, (ii) ionic concentration levels remained constant from year to year, (iii) the monthly trends were the same for each year. Table V contains the results of these tests. Significance suggests rejection of the hypothesis.

Many species did not have enough year/month combinations to be informative, thus only the following tests were considered in the subsequent analyses:

$ALKHCO_3$	B	Ca	Cl	COND
Fe	K	Mg	Na	pH
Si	SO_4	Sr		

The criterion used to choose these species was that sampling must have been done for at least three months per year for two years. Since it is not meaningful to establish month trends when only 2 months of information per year are available, many tests were excluded that were only done at the Research Division laboratory. This is due to the fact that although the Research Division laboratory carried out more tests than the TBTGS laboratory, they were only done twice a year. For such tests only the year trend conclusions were meaningful.

In the plots described above for the subset of species which had sufficient data, the first three months of the year appeared different from the other months. The data in these three months were sparse since samples could only be obtained in the winter months if there was a thaw. Months one, two and three were eliminated and the analyses of the date factor repeated.

The only changes that occurred were as follows:

1. For $ALKHCO_3$, the month trend became nonsignificant.
2. For Na, the month trend became significant while the interaction became nonsignificant.
3. For SO_4 the month trend became significant.

The month/year plots also revealed some month/year

combinations that appeared different than the rest. They were removed and the analysis repeated. In many cases the monthly trends became nonsignificant. Table VI contains descriptive statistics for the outliers and for the remaining observations omitting the outliers (in the ln scale). This suggests that a routine can be established for detecting outliers. The researcher can then investigate the properties of that date in more detail.

The year factor remained significant despite the omission of seemingly influential data. Table VII contains the means at each year for each species. However, graphs of the means at each year against concentration level showed high variation between years. Thus, no clear statement can be made that concentration levels were increasing yearly.

4. CONCLUSIONS

Analyses of variance provided evidence that:

- peizometer location is significant for the majority of species;
- stratum is significant in less than half the species though significant interaction warrants caution in accepting this conclusion for some species;
- testing site had significant influence for the majority of species;
- date was significant for almost all species. To see where the differences lie, each factor may be plotted averaged over all other factors.

Further analysis of date provided evidence that:

- a significant month trend exists for the majority of species but that this became nonsignificant when outlying dates were eliminated from the analysis;
- year was significant in most cases even if outliers were omitted;
- no clear statement could be made about year trends due to the random variation between years.

5. RECOMMENDATIONS

It is recommended that further study include the following points of investigation.

- A more rigorous procedure for detecting dates that are different than the rest should be developed. There is a body of literature dealing with this topic. After reviewing the available procedures a suitable one can be tailored to the needs of this problem.

- Sometimes data collected for a particular an ion is sparse. Since groups of ions tend to behave in similar fashion, a multivariate analysis may be useful in combining data in a meaningful way.

Submitted:

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SAB:cmh

TABLE I

SAMPLING DATES GROUPED BY LABORATORY RESPONSIBLE FOR ANALYSIS

London Monenco Ltd. (LMC)	Research Division	Thunder Bay TGS (TBTGS)
76-08-10	79-05-03	79-05-31
76-08-19	79-09-11	79-07-05
76-11-17	80-05-13	79-08-09
77-01-20	80-08-18	79-08-30
78-05-18	81-05-12	79-09-27
78-07-11	81-08-11	79-11-09
	82-05-19	79-11-29
	82-07-23	80-01-04
	82-10-15	80-02-07
	82-11-18	80-03-14
	83-05-06	80-05-06
	83-08-11	80-06-27
		80-08-11
		80-10-28
		81-03-10
		81-06-03
		81-10-28
		82-05-20
		82-07-24
		82-10-16
		82-11-19
		83-05-07
		83-08-12
		84-04-20

Note: Notation for the date is yy-mm-dd where yy is year, mm is month, and dd is day.

TABLE II

FLYASH DATA SET
SUMMARY STATISTICS
EXCLUDING DETECTION LIMITS

OBS	CHEMICAL SPECIES	NO. OF OBS. ABOVE DETECTION LIMIT	NO. OF OBS. BELOW DETECTION LIMIT	MEAN *	STANDARD * DEVIATION	MAXIMUM*	MINIMUM *
1	AG	5	225	0.00048	0.00036	0.00110	0.00020
2	AL	178	189	0.33135	0.74693	9.91000	0.04000
3	ALKCOS	6	69	47.50000	12.09545	60.00000	33.00000
4	ALKHCOS	1044	0	437.43199	200.73079	1870.00000	58.00000
5	ALKOH	0	75	.	.	.	.
6	ALKTOT	334	0	390.79940	139.02016	900.00000	70.00000
7	AS	108	265	0.00344	0.00286	0.01700	0.00050
8	B	496	326	0.42557	0.48743	3.60000	0.00200
9	BA	175	152	0.24001	0.50885	6.10000	0.00900
10	BE	2	228	0.00015	0.00007	0.00020	0.00010
11	BR	21	88	0.19952	0.07896	0.39000	0.09000
12	CA	756	0	87.80899	35.40624	211.00000	6.70000
13	CD	290	121	0.00239	0.00406	0.02200	0.00010
14	CL	721	0	16.59477	17.89716	230.00000	1.30000
15	CO	38	186	0.00574	0.00352	0.01900	0.00200
16	COND	1247	0	80.23079	35.33924	930.00000	10.00000
17	CR	120	206	0.03248	0.10787	0.50000	0.00100
18	CU	301	109	0.01865	0.03316	0.37000	0.00014
19	FE	366	44	22.16273	23.96033	161.00000	0.05000
20	HG	80	215	0.00948	0.05596	0.50007	0.00004
21	I	1	108	0.04000	.	0.04000	0.04000
22	K	721	6	2.51792	3.66932	39.00000	0.07000
23	MG	764	0	32.71126	14.63632	128.00000	3.00000
24	MN	382	21	2.21287	1.92880	25.00000	0.02000
25	MO	1	403	1.00000	.	1.00000	1.00000
26	NA	966	0	20.26299	18.57892	174.00000	1.06000
27	NI	219	155	0.01974	0.01450	0.08000	0.00138
28	NO3	198	111	1.37682	7.45881	102.00000	0.01000
29	PB	70	340	0.01040	0.01669	0.07000	0.00100
30	PH	1255	0	6.89222	0.44964	8.50000	4.10000
31	PO4	246	175	0.13288	0.26824	2.31000	0.00100
32	SB	0	6	.	.	.	.
33	SE	15	352	0.00183	0.00107	0.00430	0.00100
34	SI	377	0	13.46928	6.67080	31.00000	0.10000
35	SN	0	112	.	.	.	.
36	SO4	855	82	44.03578	76.46626	835.00000	0.10000
37	SR	628	248	0.17957	0.17380	2.00000	0.01000
38	TH	0	144	.	.	.	.
39	TI	51	244	0.57465	1.09819	5.20000	0.00100
40	U	0	70	.	.	.	.
41	V	35	293	0.00760	0.00869	0.04000	0.00100
42	ZN	134	275	0.05628	0.06510	0.40000	0.00180

* All concentrations are mg/L except pH (unitless) and COND (mS/m).

NOTE: "." Denotes missing value.

TABLE III

SIGNIFICANCE TEST RESULTS FOR EACH IONIC SPECIES

Test	Peizometer Location	Strata	Peiz Loc x Strata	Testing Location	Date	Rsq
AL	**	ns	*	*	**	.51
ALKHCO3	**	ns	**	**	**	.75
ALKTOT	**	ns	**	*	**	.68
AS	ns	ns	ns	**	**	.64
B	**	**	ns	**	**	.77
BA	**	**	**	**	**	.81
BR	*	*	*	-	**	.98
CA	**	**	**	**	**	.81
CD	**	*	*	**	**	.82
CL	**	**	**	**	**	.51
CO	ns	ns	ns	-	ns	.91
COND	**	ns	**	**	**	.67
CR	**	ns	**	-	**	.88
CU	**	ns	ns	**	**	.64
FE	**	**	ns	**	**	.62
HG	ns	ns	*	ns	ns	.85
K	**	ns	**	**	**	.69
MG	**	**	**	**	**	.73
MN	**	ns	**	**	**	.44
NA	**	ns	**	**	**	.57
NI	**	**	ns	**	**	.68
NO3	**	ns	ns	-	**	.39
PB	**	ns	ns	**	**	.83
PH	**	**	**	**	**	.66
PO4	*	ns	**	**	**	.68
SI	**	**	ns	**	**	.70
SO4	**	**	**	**	**	.57
SR	**	ns	**	**	**	.78
TI	**	*	**	-	**	.98
V	ns	ns	ns	-	ns	.89
ZN	*	ns	**	**	**	.69
No of *	3 (10%)	3 (10%)	4 (13%)	2 (68%)	0 (0%)	
No of **	24 (77%)	10 (32%)	17 (55%)	22 (88%)	28 (90%)	
No of ns	4 (13%)	18 (58%)	10 (32%)	1 (4%)	3 (10%)	
total	31	31	31	25	31	

Legend: ** significant with $p < .01$
* significant with $.01 < p < .05$
ns not significant

Note: Species with 15 or less observations above detection limit are omitted (see Table II).

TABLE I.

FLYASH DATA SET
TESTING SITE STATISTICS
NOTE THAT DETECTION LIMITS ARE IGNORED

	TESTING SITE 0			1			2			ALL		
	MEAN	LOG STD	N	MEAN	LOG STD	N	MEAN	LOG STD	N	MEAN	LOG STD	N
TEST												
AG	.	.	.	-7.82	0.63	5.00	.	.	.	-7.82	0.63	5.00
AL	.	.	.	-1.53	0.42	119.00	-1.26	0.93	59.00	-1.44	0.65	178.00
ALKCOS	.	.	.	3.83	0.27	6.00	.	.	.	3.83	0.27	6.00
ALKINCOS	6.06	0.47	516.00	5.88	0.39	454.00	6.15	0.38	74.00	5.99	0.44	1044.00
ALKTOT	5.91	0.40	255.00	5.85	0.37	79.00	.	.	.	5.90	0.39	334.00
AS	.	.	.	-5.82	0.74	71.00	-6.30	0.87	37.00	-5.98	0.82	108.00
B	-1.69	1.02	165.00	-1.19	1.20	257.00	-2.40	1.64	74.00	-1.54	1.29	496.00
BA	.	.	.	-2.74	0.45	105.00	-1.06	0.75	70.00	-2.07	1.02	175.00
BE	.	.	.	-8.86	0.49	2.00	.	.	.	-8.86	0.49	2.00
BR	.	.	.	-1.68	0.39	21.00	.	.	.	-1.68	0.39	21.00
CA	4.01	0.68	225.00	4.52	0.36	457.00	4.50	0.33	74.00	4.36	0.53	756.00
CD	.	.	.	-8.13	0.93	218.00	-4.99	0.53	72.00	-7.35	1.60	290.00
CL	2.73	0.90	191.00	2.42	0.64	456.00	2.64	0.48	74.00	2.52	0.72	721.00
CO	.	.	.	-5.33	0.60	38.00	.	.	.	-5.33	0.60	38.00
COND	4.39	0.35	725.00	4.24	0.30	448.00	4.16	0.31	74.00	4.32	0.34	1247.00
CR	.	.	.	-4.95	1.30	120.00	.	.	.	-4.95	1.30	120.00
CU	.	.	.	-5.36	1.03	227.00	-3.29	0.80	74.00	-4.85	1.32	301.00
FE	.	.	.	1.84	2.14	292.00	2.58	1.32	74.00	1.99	2.02	366.00
HG	.	.	.	-7.93	1.29	42.00	-5.77	1.60	38.00	-6.90	1.80	80.00
I	.	.	.	-3.22	.	1.00	.	.	.	-3.22	.	1.00

(CONTINUED)

TA IV NTI

FLYASH DATA SET
TESTING SITE STATISTICS
NOTE THAT DETECTION LIMITS ARE IGNORED

	TESTING SITE 0			1			2			ALL		
		LOG			LOG			LOG			LOG	
TEST	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N	MEAN	STD	N
K	1.01	0.98	196.00	0.27	0.68	451.00	0.48	0.69	74.00	0.49	0.84	721.00
MG	3.16	0.55	233.00	3.48	0.43	457.00	3.47	0.41	74.00	3.38	0.49	764.00
MN	.	.	.	0.47	0.89	308.00	0.65	0.79	74.00	0.51	0.88	382.00
MO	.	.	.	0.00	.	1.00	.	.	.	0.00	.	1.00
NA	2.83	0.61	435.00	2.80	0.62	457.00	2.20	0.78	74.00	2.77	0.65	966.00
NI	.	.	.	-4.36	0.81	185.00	-3.48	0.41	34.00	-4.22	0.83	219.00
NO3	.	.	.	-0.94	1.29	198.00	.	.	.	-0.94	1.29	198.00
PB	.	.	.	-5.50	1.01	66.00	-2.88	0.27	4.00	-5.35	1.16	70.00
PH	1.91	0.05	727.00	1.97	0.07	454.00	1.87	0.03	74.00	1.93	0.06	1255.00
PO4	.	.	.	-2.53	1.01	180.00	-3.79	1.65	66.00	-2.87	1.33	246.00
SE	.	.	.	-6.45	0.54	15.00	.	.	.	-6.45	0.54	15.00
SI	.	.	.	2.54	0.48	304.00	1.86	1.25	73.00	2.41	0.75	377.00
SO4	2.83	1.84	337.00	2.26	1.91	444.00	2.73	1.28	74.00	2.53	1.86	855.00
SR	-2.28	0.87	284.00	-2.02	0.61	271.00	-1.20	0.60	73.00	-2.04	0.81	628.00
TI	.	.	.	-3.95	3.04	51.00	.	.	.	-3.95	3.04	51.00
V	.	.	.	-5.36	0.97	35.00	.	.	.	-5.36	0.97	35.00
ZN	.	.	.	-3.57	0.79	116.00	-1.89	0.45	18.00	-3.34	0.95	134.00

Units of the original concentrations were mg/L except pH (unitless) and COND (mS/m).
NOTE: "." Denotes missing value.

TABLE V

SIGNIFICANCE TEST RESULTS FOR YEAR AND MONTH FACTORS OMITTING DATES BEFORE JANUARY 1, 1979

Test	Month (continuous)	Year (category)	Month *Year
AL	ns	**	ns
ALKHCO3	*	**	**
ALKTOT	**	**	ns
AS	**	*	**
B	**	**	**
BA	ns	*	-
BR	**	-	-
CA	**	**	**
CD	ns	**	ns
CL	**	**	**
CO	ns	ns	-
COND	**	**	**
CR	**	**	-
CU	ns	**	**
FE	ns	**	**
HG	**	ns	-
K	ns	**	**
MG	**	**	**
MN	ns	ns	**
NA	ns	**	*
NI	**	**	**
NO3	ns	**	**
PB	**	*	ns
PH	ns	**	**
PO4	ns	**	ns
SI	**	**	**
SO4	ns	**	**
SR	**	**	**
TI	**	**	**
V	ns	ns	ns
ZN	ns	**	ns
No of *	1 (3%)	3 (10%)	1 (4%)
No of **	15 (48%)	23 (77%)	18 (69%)
No of ns	15 (48%)	4 (13%)	7 (27%)
total	31	30	26

Legend: ** significant with $p < .01$
* significant with $.01 < p < .05$
ns not significant

Note: Species with less than 16 observations above detection limit are omitted (see Table II).

TABLE VI

SUMMARY STATISTICS OMITTING OUTLIERS LN TRANSFORMED DATA

Test	Outlier year	Outlier mo.	Outlier Stats mean	std	n	Stats of Remaining Obs mean	std	n
ALKHCO3	1979	7	6.65	0.30	34	5.95	0.42	915
B	1982	all	0.24	0.31	76	-1.24	0.95	344
CA	1981	6	3.37	0.46	41	4.50*	0.35	600
CA	1981	10	3.15	0.40	41	4.50*	0.35	600
COND	1981	all	4.15	0.39	169	4.37	0.33	991
FE	1982	5	-0.02	2.23	22	2.01	2.05	270
K	1980	6	2.51	0.49	39	0.36	0.70	601
MG	1980	5	2.93	0.68	78	3.47*	0.41	566
MG	1981	6	2.93	0.32	41	3.47*	0.41	566
SI	1980	8	1.65	0.28	32	2.65	0.39	272

Units of original concentrations were mg/L except COND (mS/m).

Note: If a test had more than one outlier, the mean of the remaining observations was calculated omitting all outliers.

TABLE VII

FLYASH DATA SET
YEARLY STATISTICS
NOTE THAT DETECTION LIMITS ARE IGNORED

	YEAR						
	1979	1980	1981	1982	1983	1984	ALL
TEST							
AG	.	.	-7.82	.	.	.	-7.82
AL	-1.61	-1.38	-1.21	.	-1.86	.	-1.53
ALKCOS	.	.	.	3.83	.	.	3.83
ALKNCOS	6.23	5.83	5.89	5.86	5.97	.	5.97
ALKTOT	.	.	5.89	5.90	.	5.91	5.90
AS	.	-6.04	-5.66	-6.21	-6.04	.	-5.82
B	-1.90	-1.74	-1.40	0.24	-2.03	.	-1.39
BA	.	-2.74	.	-2.79	-1.61	.	-2.74
BE	.	.	-8.86	.	.	.	-8.86
BR	.	.	-1.68	.	.	.	-1.68
CA	4.55	4.45	3.84	4.53	4.58	.	4.35
CD	-7.98	-7.48	-8.66	-8.59	-8.12	.	-8.13
CL	2.37	2.78	2.41	2.38	2.44	.	2.51
CO	.	.	.	-5.34	-5.33	.	-5.33
CORD	4.40	4.31	4.15	4.34	4.45	4.40	4.34
CR	-0.69	-4.68	.	-5.99	-4.94	.	-4.95
CU	-4.97	-5.71	-5.69	-4.98	-5.37	.	-5.36
FE	2.45	1.90	1.99	0.62	2.18	.	1.84
MG	-8.44	-9.36	-7.12	-7.18	-8.06	.	-7.93
I	.	.	-3.22	.	.	.	-3.22
K	0.52	0.81	0.61	0.18	0.14	.	0.49
MN	3.45	3.25	3.32	3.47	3.60	.	3.37

TABLE VII (continued)

FLYASH DATA SET
YEARLY STATISTICS
NOTE THAT DETECTION LIMITS ARE IGNORED

	YEAR						
TEST	1979	1980	1981	1982	1983	1984	ALL
MN	0.66	0.50	0.30	0.41	0.53	.	0.47
MO	.	.	.	0.00	.	.	0.00
NA	2.81	2.91	2.81	2.72	2.75	.	2.81
NI	.	-4.31	-4.57	-4.29	-4.23	.	-4.36
NO3	-1.10	-0.78	-0.36	-1.45	0.26	.	-0.94
PB	-6.00	-4.69	-5.75	-5.51	-6.21	.	-5.50
PH	1.92	1.95	1.93	1.94	1.93	1.86	1.93
PO4	-4.37	-0.29	-2.51	-2.73	-1.38	.	-2.53
SE	-6.42	.	-6.91	.	.	.	-6.45
SI	2.61	2.26	2.72	2.60	2.53	.	2.54
SO4	2.44	2.89	2.03	2.59	2.35	.	2.51
SR	-2.76	-1.98	-2.04	-1.79	-1.94	.	-2.15
TI	.	-5.78	.	-0.66	0.83	.	-3.95
V	-5.22	-5.64	-4.49	-5.58	-5.12	.	-5.36
ZN	-3.88	-3.05	-3.57	-3.80	-3.69	.	-3.57

Units of original concentrations were mg/L except pH (unitless) and COND (mS/m).

FIGURE 1
FLYASH DATA SET
RESIDUAL PLOTS
NOTE THAT DETECTION LIMITS ARE IGNORED
TEST=B

PLOT OF RESHVHAT LEGEND: A = 1 OBS, B = 2 OBS, ETC.

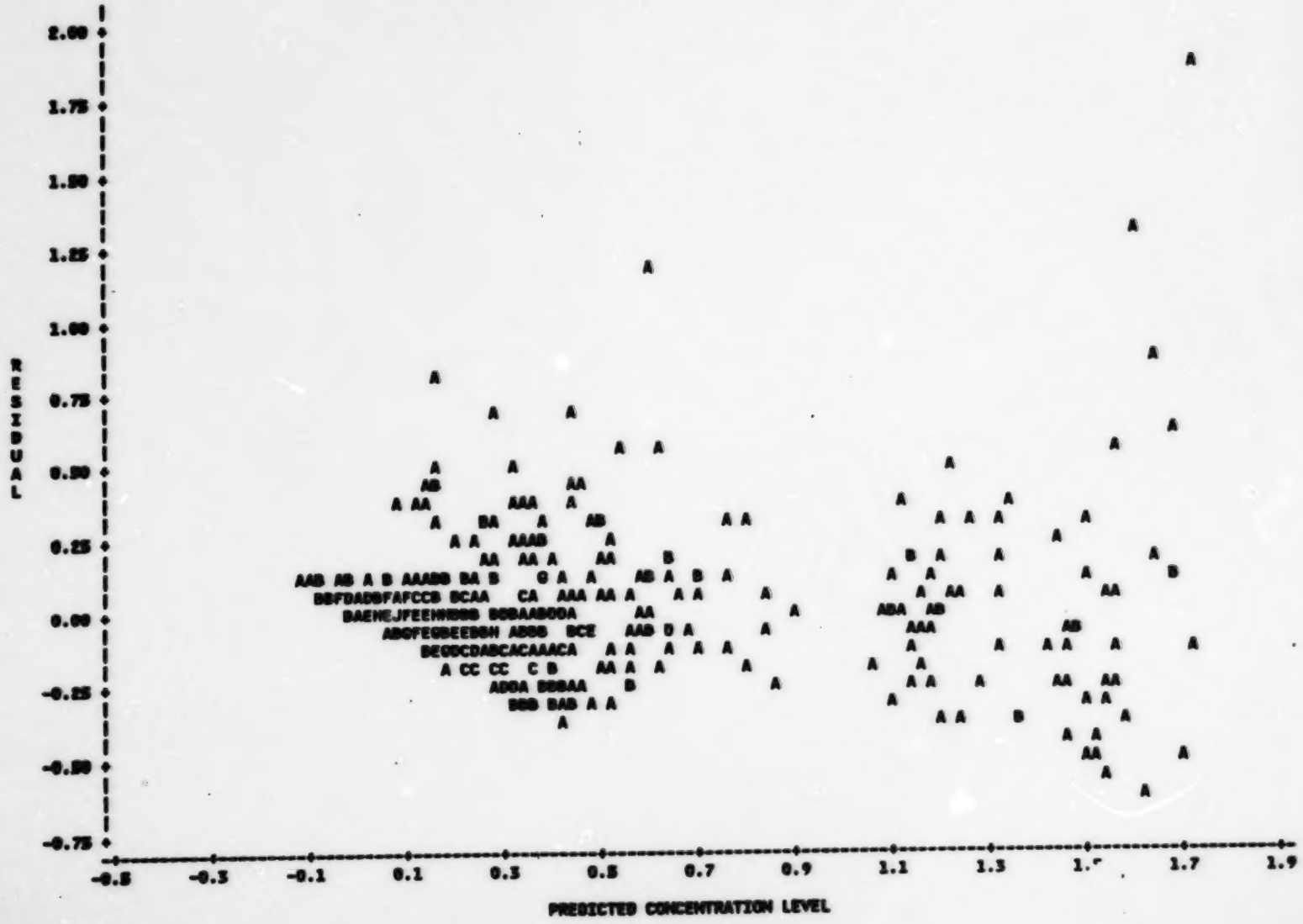


FIGURE 1: (CONTINUED)
FLYASH DATA SET
RESIDUAL PLOTS
NOTE THAT DETECTION LIMITS ARE IGNORED
TEST=PH

PLOT OF RESHYHAT LEGEND: A = 1 OBS, B = 2 OBS, ETC.

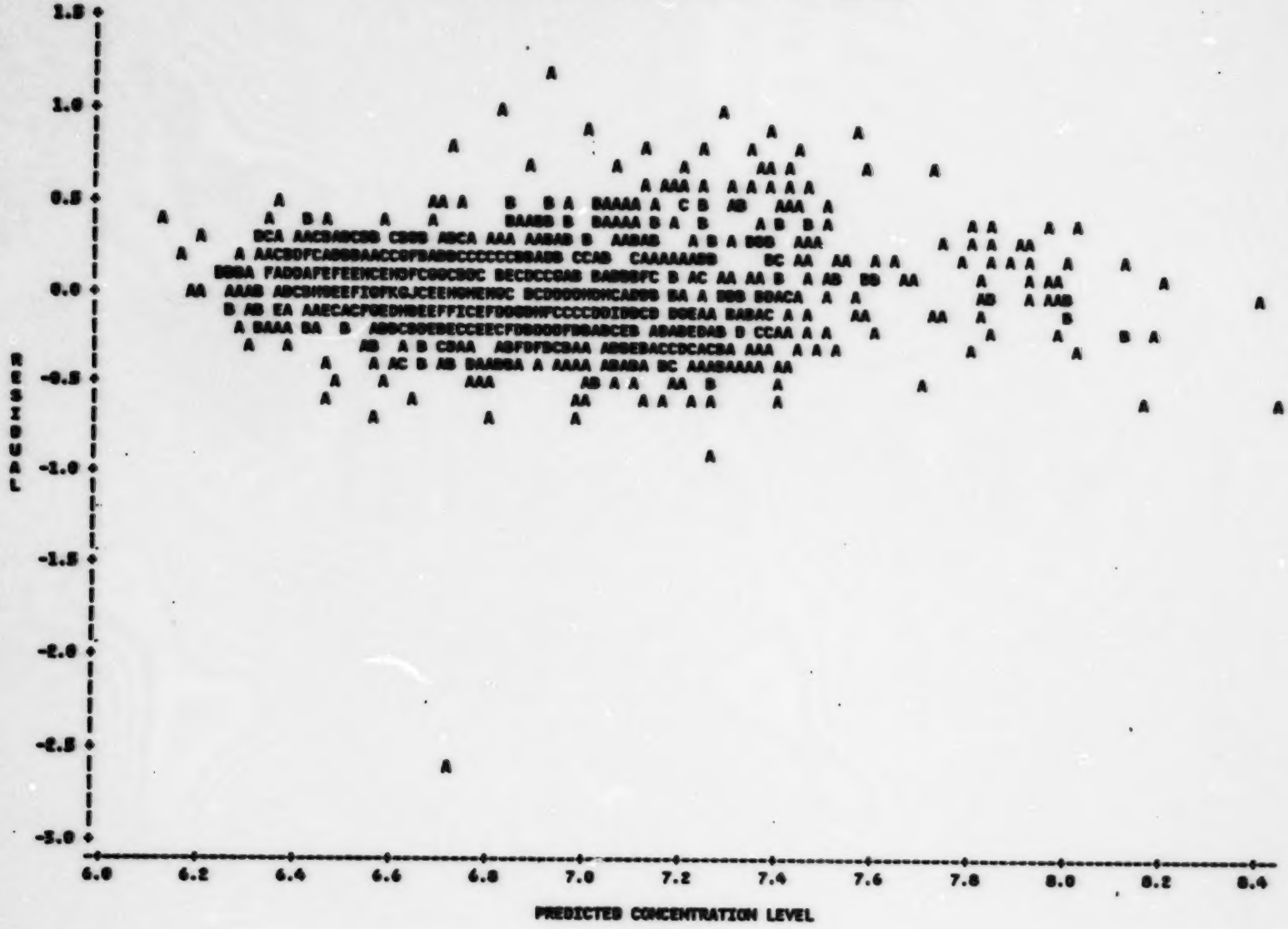


FIGURE 1: (CONTINUED)
FLYASH DATA SET
RESIDUAL PLOTS
NOTE THAT DETECTION LIMITS ARE IGNORED
TEST=SR

PLOT OF RES*YHAT LEGEND: A = 1 OBS, B = 2 OBS, ETC.

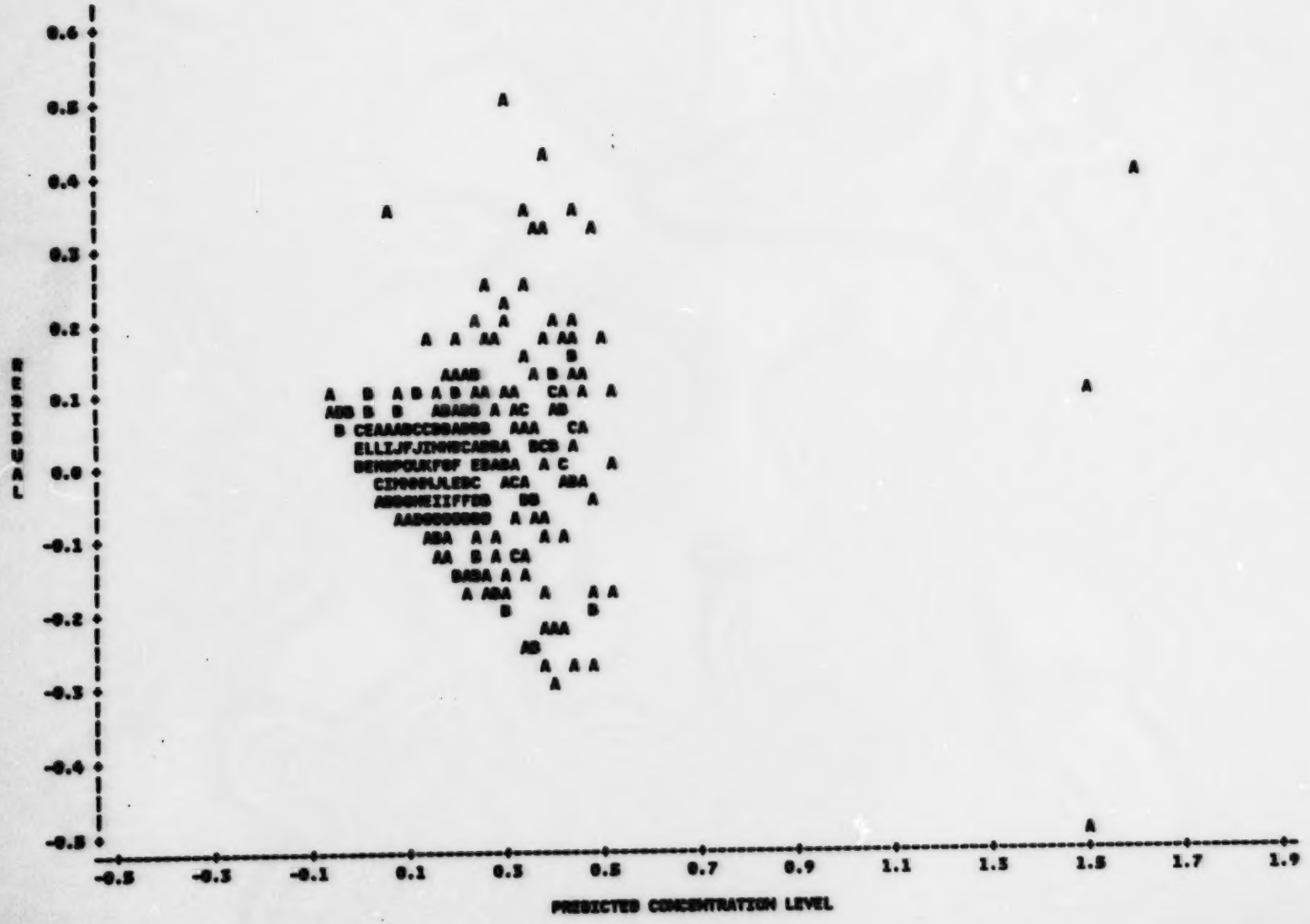


FIGURE 2:

NORMAL PROBABILITY PLOT
TEST=0

UNIVARIATE

VARIABLE=RES RESIDUAL

MOMENTS

N	496	SUM WGTS	496
MEAN	1.943E-15	SUM	9.637E-13
STD DEV	0.223808	VARIANCE	0.0500902
SKEWNESS	2.28248	KURTOSIS	13.9442
USS	24.7947	CSS	24.7947
CV	1.152E+16	STD MEAN	0.0100495
T:MEAN=0	1.933E-13	PROB>|T|	1
SGN RANK	-7243	PROB>|S|	0.0233428
NUM ^= 0	496		
D:NORMAL	0.134082	PROB>D	<0.01

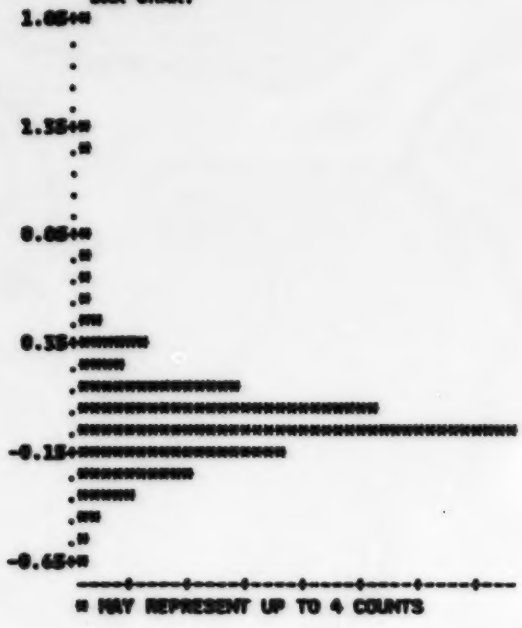
QUANTILES(DEF=4)

100% MAX	1.87586	99%	0.785813
75% Q3	0.0690423	95%	0.373575
50% MED	-0.0157799	90%	0.230566
25% Q1	-0.119213	10%	-0.236401
0% MIN	-0.611061	5%	-0.296074
		1%	-0.492997
RANGE	2.48692		
Q3-Q1	0.188256		
MODE	-0.611061		

EXTREMES

LOWEST	HIGHEST
-0.611061	0.783276
-0.543046	0.868451
-0.522951	1.2029
-0.494092	1.2965
-0.492963	1.87586

BAR CHART



BOXPLOT

NORMAL PROBABILITY PLOT

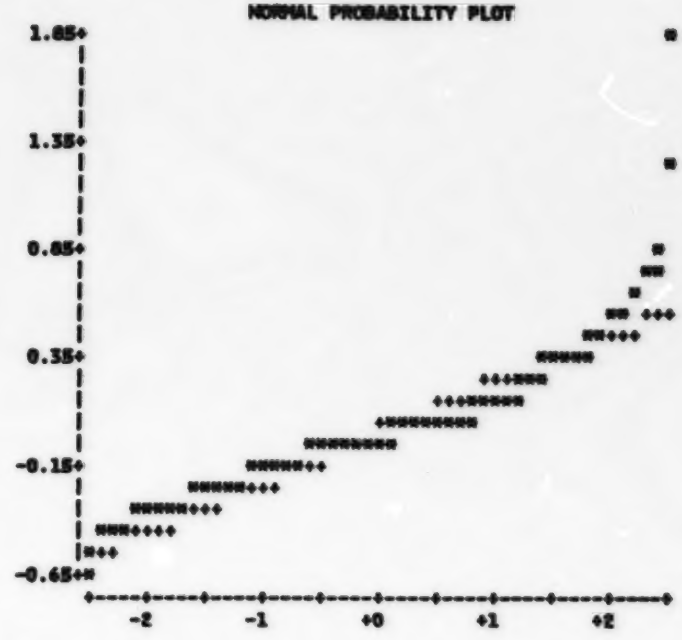


FIGURE 2: (CONTINUED)

NORMAL PROBABILITY PLOT
TEST=PH

UNIVARIATE

VARIABLE=RES RESIDUAL

MOMENTS

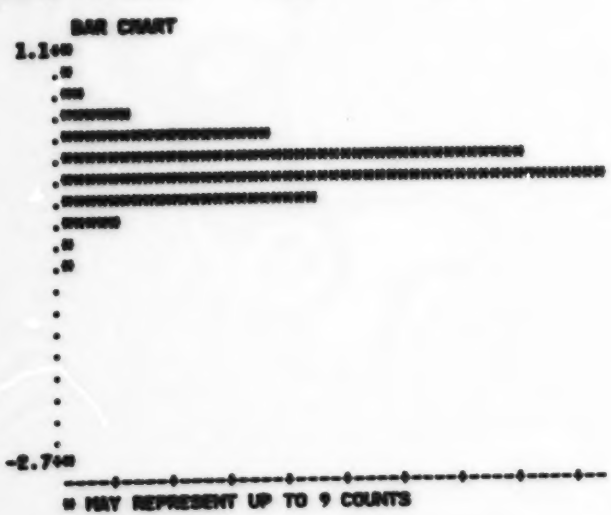
N	1255	SUM WGTS	1255
MEAN	2.213E-13	SUM	2.777E-10
STD DEV	0.257947	VARIANCE	0.0663302
SKEWNESS	-0.391104	KURTOSIS	9.26707
USS	85.1781	CSS	85.1781
CV	1.164E+14	STD MEAN	0.00726999
T:MEAN=0	3.044E-11	PROB>|T|	1
SGN RANK	-12045	PROB>|S|	0.348298
NUM ^= 0	1255		
W:NORMAL	0.9481404	PROB>W	<0.01

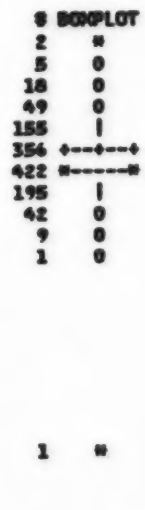
QUANTILES(DEF=4)

100% MAX	1.18712	99%	0.735187
75% Q3	0.142466	95%	0.435165
50% MED	-0.0115632	90%	0.298428
25% Q1	-0.147012	10%	-0.293369
0% MIN	-2.61742	5%	-0.376934
		1%	-0.572763
RANGE	3.80454		
Q3-Q1	0.289478		
MODE	-0.136016		

EXTREMES

LOWEST	HIGHEST
-2.61742	0.920442
-0.865445	0.936363
-0.699007	0.973395
-0.678914	1.01426
-0.650243	1.18712





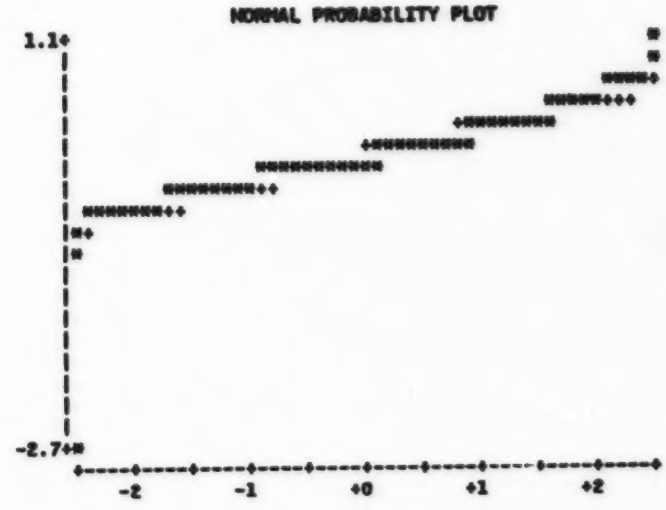


FIGURE 2: (CONTINUED)

NORMAL PROBABILITY PLOT
TEST=SR

UNIVARIATE

VARIABLE=RES RESIDUAL

MOMENTS

N	628	SUM WGTS	628
MEAN	2.094E-15	SUM	1.315E-12
STD DEV	0.0863553	VARIANCE	0.00745724
SKEWNESS	0.582674	KURTOSIS	7.22482
USS	4.67569	CSS	4.67569
CV	4.124E+15	STD MEAN	0.00344595
T:MEAN=0	6.077E-13	PROB>|T|	1
SUM RANK	-3507	PROB>|S|	0.440757
NUM ^= 0	628		
W:NORMAL	0.138942	PROB>D	<0.01

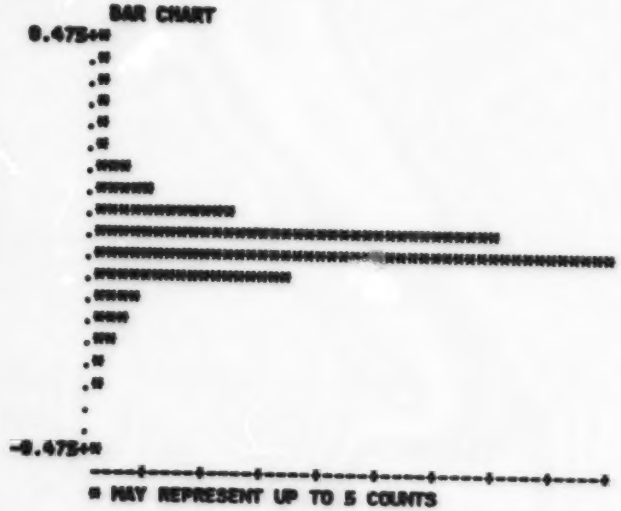
QUANTILES(DEF=4)

100% MAX	0.494679	99%	0.340932
75% Q3	0.0270739	95%	0.125408
50% MED	0.000109332	90%	0.0804486
25% Q1	-0.0360634	10%	-0.071105
0% MIN	-0.493233	5%	-0.139122
		1%	-0.255605
RANGE	0.987912		
Q3-Q1	0.0631373		
MODE	-0.0676373		

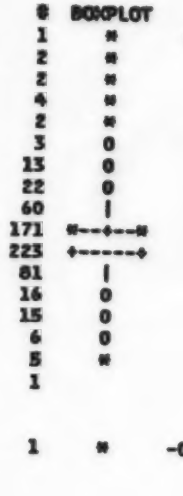
EXTREMES

LOWEST	HIGHEST
-0.493233	0.351237
-0.299898	0.353367
-0.277658	0.402015
-0.276858	0.42335
-0.272566	0.494679

BAR CHART



* MAY REPRESENT UP TO 5 COUNTS



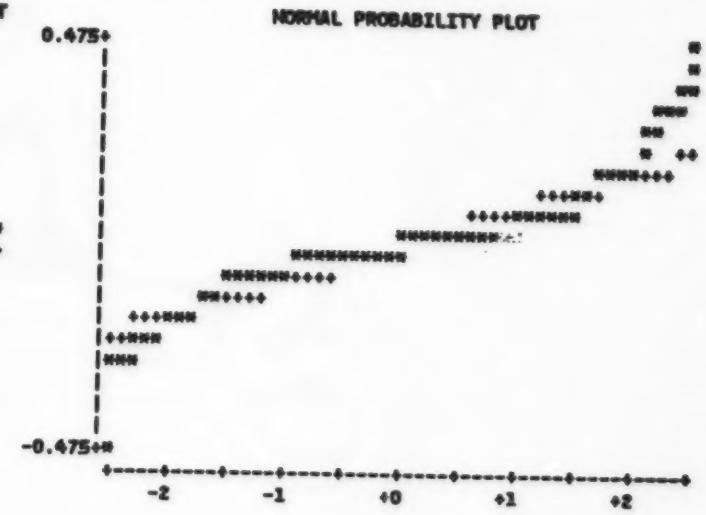


FIGURE 3:
FLYASH DATA SET
RESIDUAL PLOTS
LOG TRANSFORM DATA
NOTE THAT DETECTION LIMITS ARE IGNORED
TEST=6

PLOT OF RES*YHAT LEGEND: A = 1 OBS, B = 2 OBS, ETC.

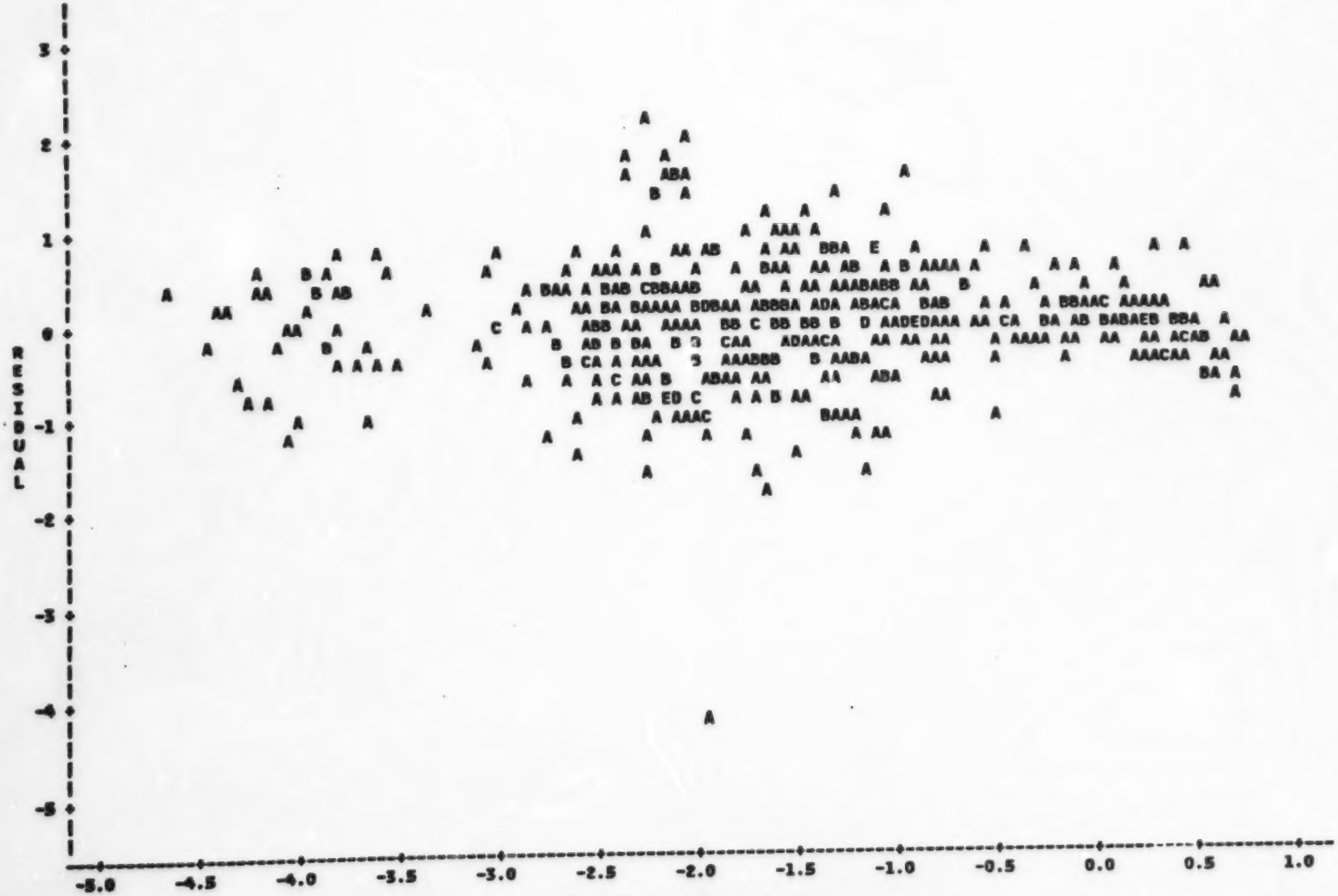


FIGURE 3: (CONTINUED)
FLYASH DATA SET
RESIDUAL PLOTS
LOG TRANSFORM DATA
NOTE THAT DETECTION LIMITS ARE IGNORED
TEST=PH

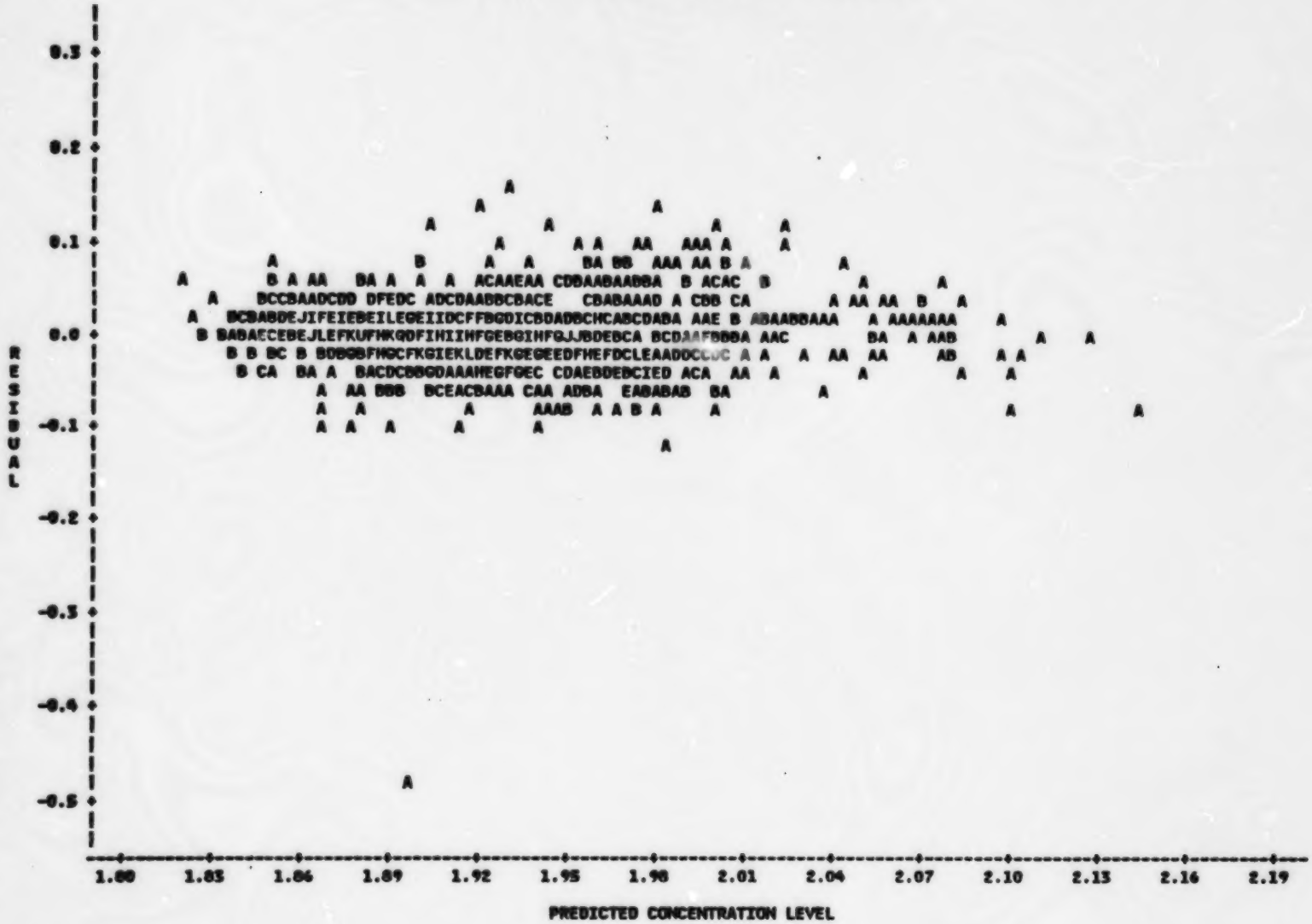


FIGURE 3: (CONTINUED)
FLYASH DATA SET
RESIDUAL PLOTS
LOG TRANSFORM DATA
NOTE THAT DETECTION LIMITS ARE IGNORED
TEST=SR

PLOT OF RES*YHAT LEGEND: A = 1 OBS, B = 2 OBS, ETC.

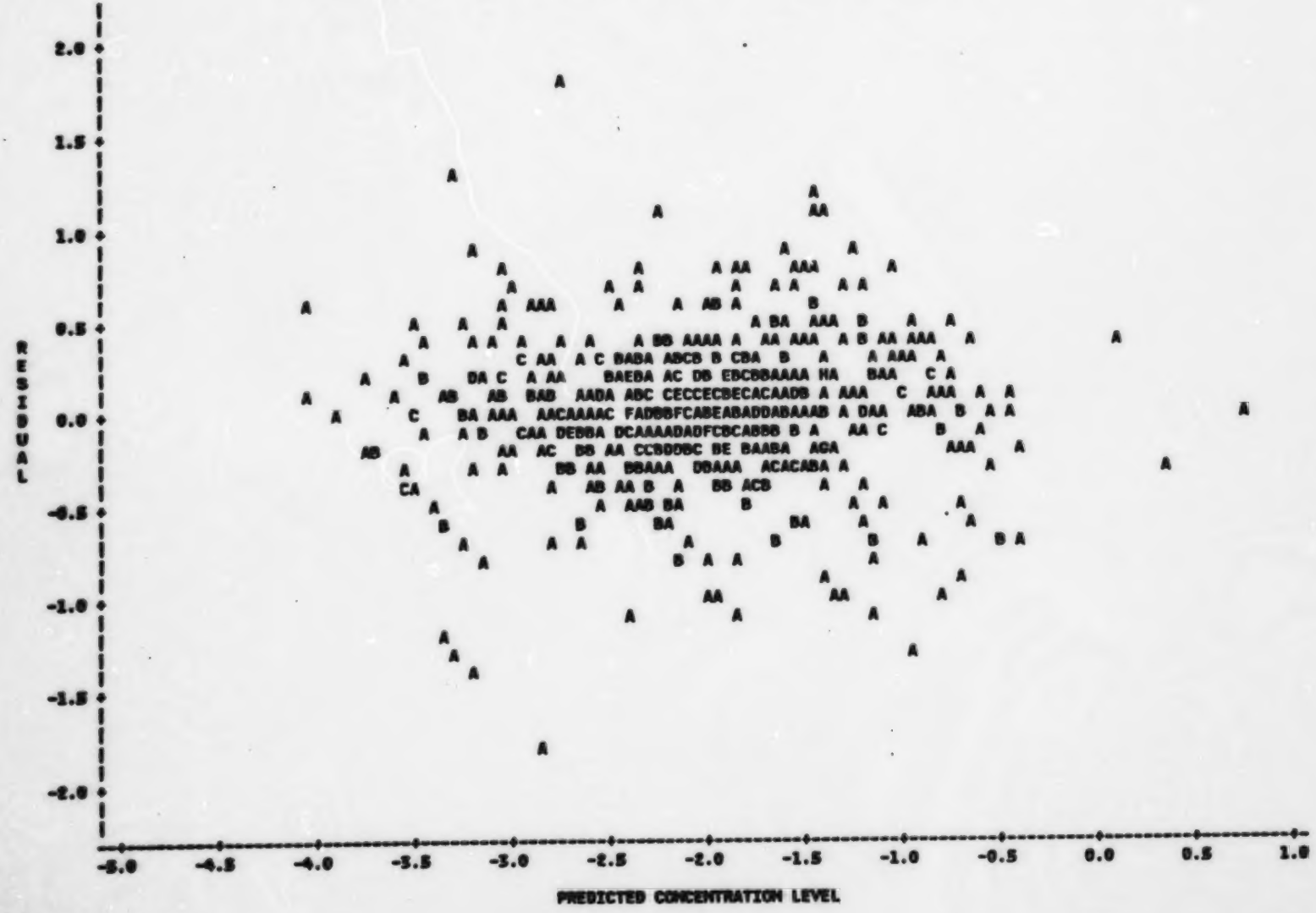


FIGURE 4:

NORMAL PROBABILITY PLOT
TEST=B

UNIVARIATE

VARIABLE=RES RESIDUAL

MOMENTS

N	496	SUM WGTS	496
MEAN	-2.678E-14	SUM	-1.328E-11
STD DEV	0.615801	VARIANCE	0.379211
SKEWNESS	-0.489406	KURTOSIS	5.00498
USS	187.71	CSS	187.71
CV	-2.307E+15	STD MEAN	0.0276503
T:MEAN=0	-9.688E-13	PROB>|T|	1
SGN RANK	477	PROB>|S|	0.881394
NUM ^= 0	496		
W:NORMAL	0.9867191	PROB<W	<0.01

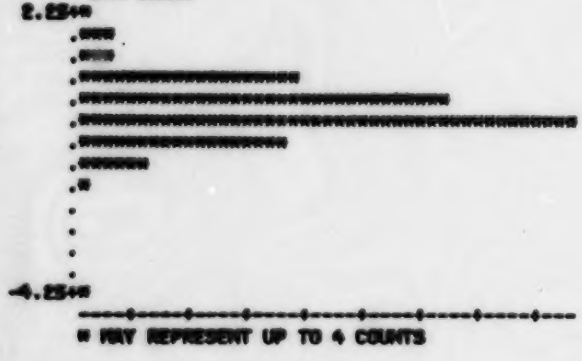
QUANTILES(DEF=4)

100%	MAX	2.1884	99%	1.65721
75%	Q3	0.34399	95%	0.893024
50%	MED	-2.546E-15	90%	0.717292
25%	Q1	-0.340057	10%	-0.735123
0%	MIN	-4.27617	5%	-1.01677
			1%	-1.50963
	RANGE	6.46457		
	Q3-Q1	0.684047		
	MODE	-4.27617		

EXTREMES

LOWEST	HIGHEST
-4.27617	1.65807
-1.88049	1.72688
-1.64369	1.75201
-1.64282	1.99453
-1.50551	2.1884

BAR CHART



MAY REPRESENT UP TO 4 COUNTS

#	BOXPLOT
2	0
10	0
11	0
76	|
127	#--+--#
171	+------+
72	|
22	|
4	0
1	#

NORMAL PROBABILITY PLOT

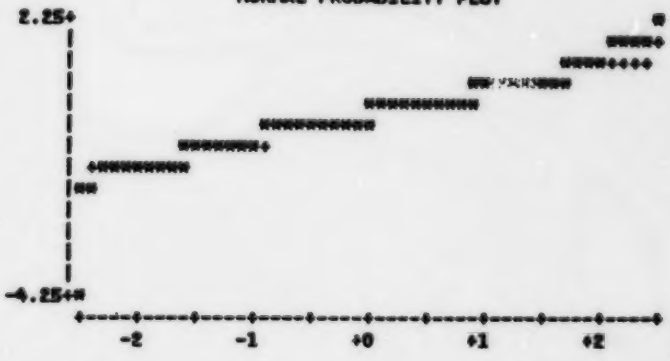


FIGURE 4: (CONTINUED)

NORMAL PROBABILITY PLOT
TEST=PH

UNIVARIATE

VARIABLE=RES RESIDUAL

MOMENTS

N	1258	SUM WGTS	1258
MEAN	3.634E-14	SUM	4.561E-11
STD DEV	0.0374491	VARIANCE	0.00140244
SKEWNESS	-1.48001	KURTOSIS	22.8674
USS	1.75866	CSS	1.75866
CV	1.031E+14	STD MEAN	0.00105711
T:MEAN=0	3.438E-11	PROB>|T|	1
SGN RANK	-6714	PROB>|S|	0.601131
NUM ^= 0	1258		
W:NORMAL	0.9468918	PROB>W	<0.01

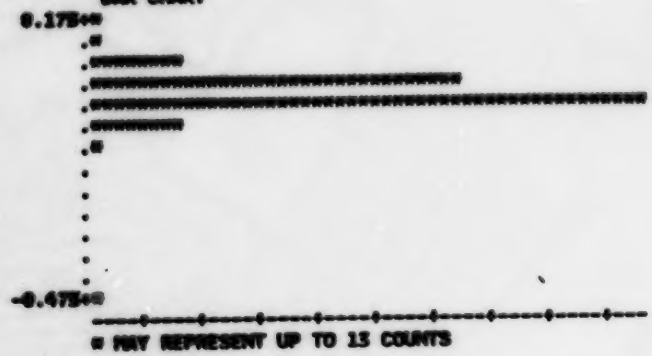
QUANTILES(DEF=4)

100% MAX	0.161897	99%	0.10014
75% Q3	0.0206114	95%	0.0617313
50% MED	-.00112751	90%	0.0426168
25% Q1	-0.0209521	10%	-0.0414576
0% MIN	-0.486293	5%	-0.0538253
		1%	-0.0837672
RANGE	0.64819		
Q3-Q1	0.0415635		
MODE	-0.486293		

EXTREMES

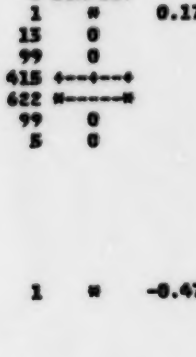
LOWEST	HIGHEST
-0.486293	0.119245
-0.125834	0.122037
-0.10544	0.134629
-0.102918	0.134651
-0.100722	0.161896

BAR CHART



MAY REPRESENT UP TO 13 COUNTS

0 BOXPLOT



NORMAL PROBABILITY PLOT

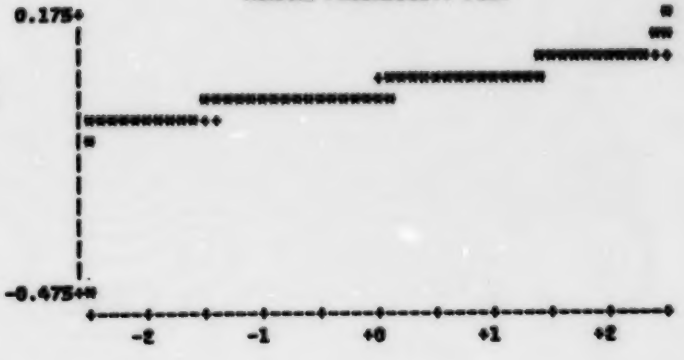


FIGURE 4: (CONTINUED)

NORMAL PROBABILITY PLOT
TEST=SR

UNIVARIATE

VARIABLE=RES RESIDUAL

MOMENTS

N	628	SUM WGTS	628
MEAN	-2.970E-14	SUM	-1.865E-11
STD DEV	0.380159	VARIANCE	0.144521
SKEWNESS	-0.22435	KURTOSIS	2.59609
USS	90.6146	CSS	90.6146
CV	-1.280E+15	STD MEAN	0.01517
T:MEAN=0	-1.958E-12	PROB>|T|	1
SGN RANK	2713	PROB>|S|	0.55094
NUM ^= 0	628		
W:NORMAL	0.9706468	PROB>W	<0.01

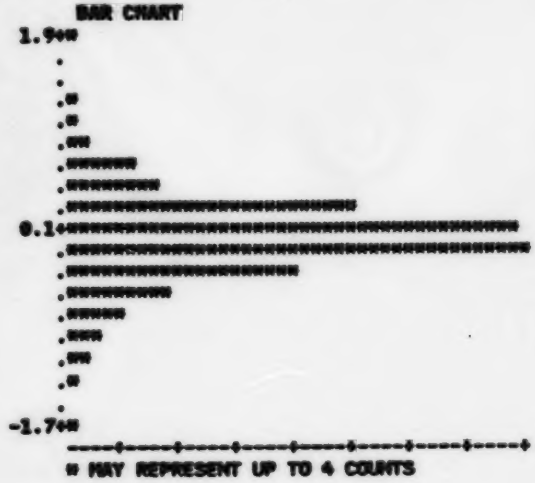
QUANTILES(DEF=4)

100% MAX	1.83782	99%	1.01087
75% Q3	0.206341	95%	0.628567
50% MED	0.00864659	90%	0.419787
25% Q1	-0.189571	10%	-0.424811
0% MIN	-1.77945	5%	-0.666378
		1%	-1.14591
RANGE	3.61727		
Q3-Q1	0.395912		
MODE	-0.189603		

EXTREMES

LOWEST	HIGHEST
-1.77945	1.05973
-1.3845	1.09147
-1.29594	1.22472
-1.26027	1.26881
-1.24271	1.83782

BAR CHART



#	BOXPLOT
1	*
2	0
3	0
8	0
22	|
32	|
98	+------+
153	*--+--*
159	+------+
80	|
33	|
17	|
10	0
5	0
4	0
1	*

NORMAL PROBABILITY PLOT

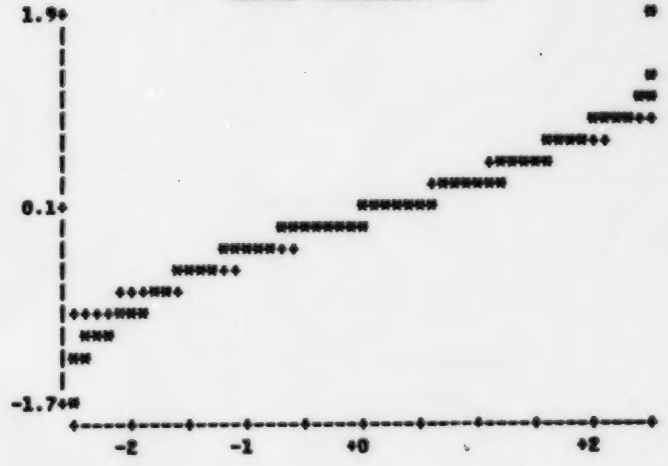
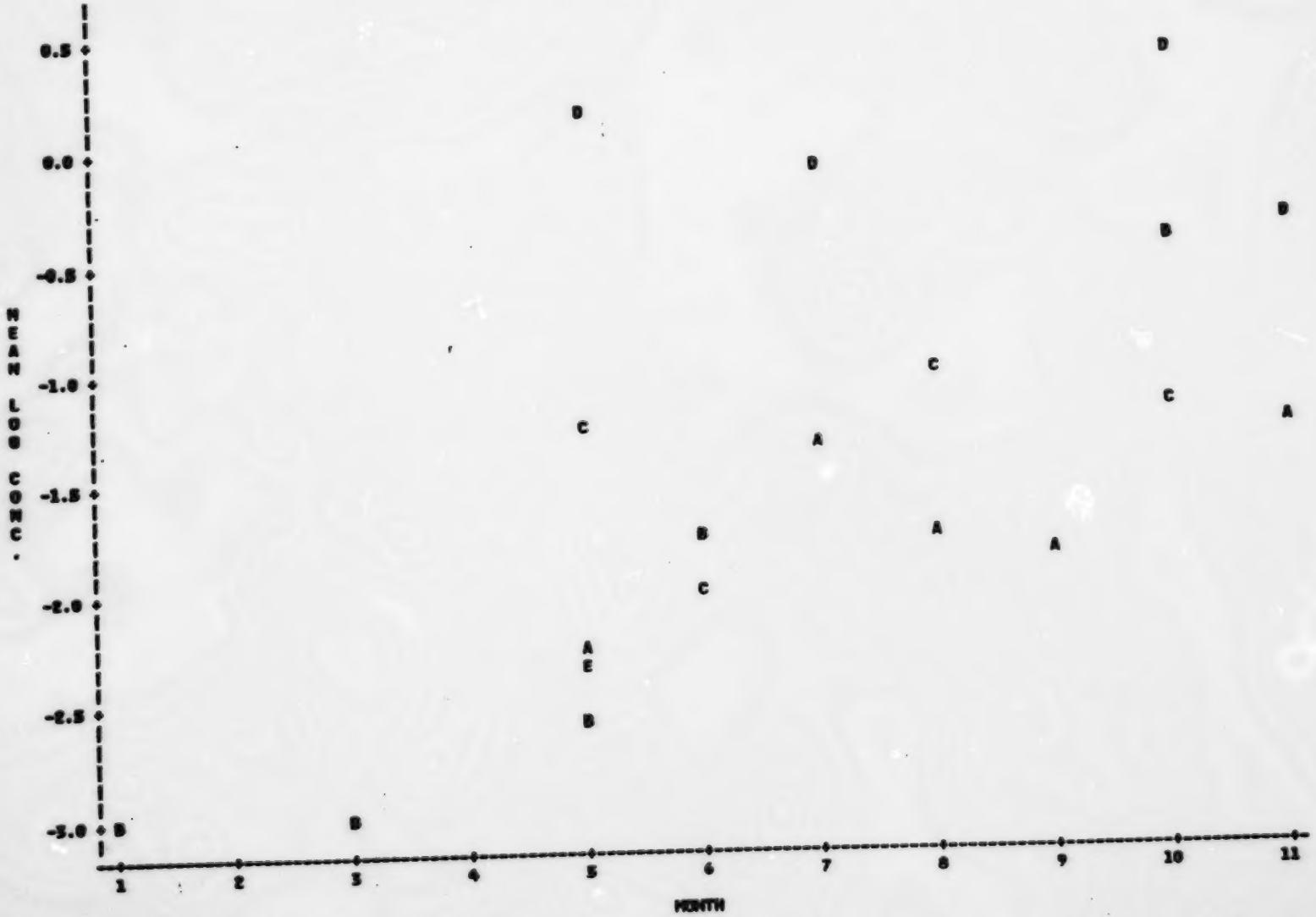
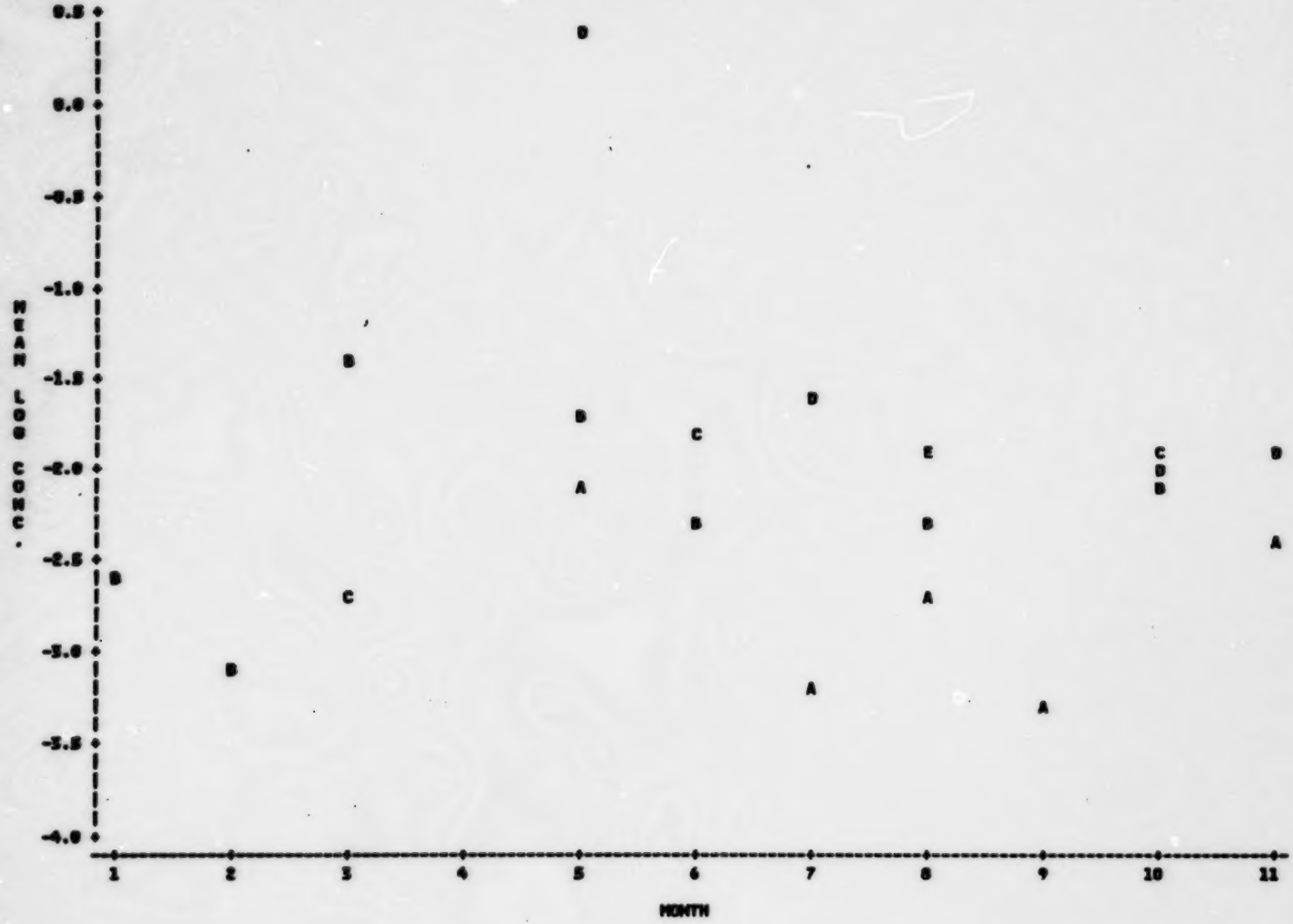


FIGURE 5:
FLYASH DATA SET
MEAN LOG CONCENTRATION VS. MONTH FOR EACH YEAR
NOTE THAT DETECTION LIMITS ARE IGNORED
LEGEND: A = 1979 B = 1980 C = 1981
D = 1982 E = 1983 F = 1984
TEST=S



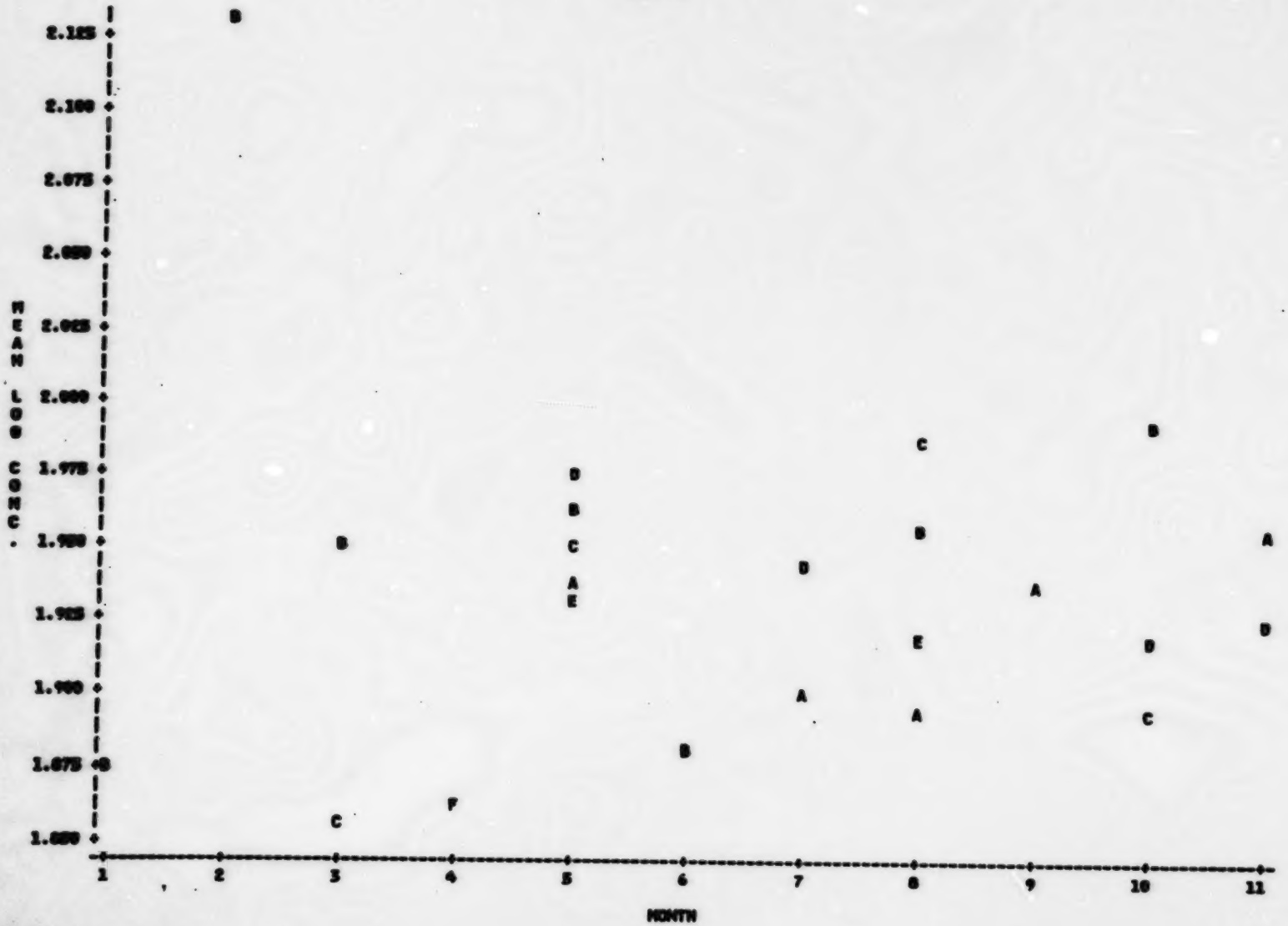
NOTE: 1 OBS HIDDEN

FIGURE 8: (CONTINUED)
FLYASH DATA SET
MEAN LOG CONCENTRATION VS. MONTH FOR EACH YEAR
NOTE THAT DETECTION LIMITS ARE IGNORED
LEGEND: A = 1979 B = 1980 C = 1981
D = 1982 E = 1983 F = 1984
TEST=SR



NOTE: 1 OBS HIDDEN

FIGURE 5: (CONTINUED)
FLYASH DATA SET
MEAN LOG CONCENTRATION VS. MONTH FOR EACH YEAR
NOTE THAT DETECTION LIMITS ARE IGNORED
LEGEND: A = 1979 B = 1980 C = 1981
D = 1982 E = 1983 F = 1984
TEST=PH



NOTE: 1 OBS HIDDEN